S.1A

REPORT

OF THE

SIXTY-SEVENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

TORONTO IN AUGUST 1897.

BRITISH MUSEUM NATURAL HISTORY.

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[*An asterisk * indicates that the title only is given. The mark † indicates the same but a reference is given to the journal or newspaper where it is published* in extenso.]

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Erratum

Page 286, *for* Dr. W. N. PERKIN, *read* Dr. W. H. PERKIN.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.

2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee not less than two years in advance [1]; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons :—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.[2]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[3]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[4] and of preparing Reports

[1] Revised by the General Committee, Liverpool, 1896.

[2] Revised, Montreal, 1884.

[3] Passed, Edinburgh, 1871.

[4] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become

thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the Sectional Committee, after which their functions as an Organising Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee except for Thursday and Saturday.[5]

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before......................., addressed to the General Secretaries, at the office of the Association. 'For Section........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant General Secretary *before the conclusion of the Meeting.*

[1] Sheffield, 1879. [2] Swansea, 1880. [3] Edinburgh, 1871.
[4] The meeting on Saturday is optional, Southport, 1883. [5] Nottingham, 1893.

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxxi), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices regarding Grants of Money.[2]

1. No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the Rules of the Association.
2. In grants of money to Committees the Association does not contemplate the payment of personal expenses to the Members.
3. Committees to which grants of money are entrusted by the Association for the prosecution of particular Researches in Science are appointed for one year only. If the work of a Committee cannot be completed in the year, and if the Sectional Committee desire the work to be continued, application for the reappointment of the Committee for another year must be made at the next meeting of the Association.
4. Each Committee is required to present a Report, whether final or interim, at the next meeting of the Association after their appointment or reappointment. Interim Reports must be submitted in writing, though not necessarily for publication.

[1] Revised by the General Committee, Bath, 1888.
[2] Revised by the General Committee at Ipswich, 1895.

5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor A. W. Rücker, F.R.S., for such portion of the sums granted as may from time to time be required.
6. Grants of money sanctioned at a meeting of the Association expire on June 30 following. The Treasurer is not authorised after that date to allow any claims on account of such grants.
7. The Chairman of a Committee must, before the meeting of the Association next following after the appointment or reappointment of the Committee, forward to the Treasurer a statement of the sums which have been received and expended, with vouchers. The Chairman must also return the balance of the grant, if any, which has been received and not spent; or, if further expenditure is contemplated, he must apply for leave to retain the balance.
8. When application is made for a Committee to be reappointed, and to retain the balance of a former grant which is in the hands of the Chairman, and also to receive a further grant, the amount of such further grant is to be estimated as being additional to, and not inclusive of, the balance proposed to be retained.
9. The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such report has been received.
10. Members and Committees who may be entrusted with sums of money for collecting specimens of Natural History are requested to reserve the specimens so obtained to be dealt with by authority of the Association.
11. Committees are requested to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus will be useful for continuing the research in question, or for other scientific purposes.
12. All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association when not employed in scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and Sectional Committee, except for Thursday and Saturday.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

Presidents of the Association in former years are *ex officio* members of the Committee of Recommendations.[1]

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[2]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[3]

[1] Passed by the General Committee at Newcastle, 1863.
[2] Passed by the General Committee at Birmingham, 1865.
[3] Passed by the General Committee at Leeds, 1890.

Corresponding Societies.[1]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Assistant General Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Assistant General Secretary of the Association, a schedule, properly filled up, which will be issued by him, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to

[1] Passed by the General Committee, 1884.

the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of

[1] Passed by the General Committee at Belfast, 1874.

whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year—observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of the General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh. The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851	The Lord Rendlesham, M.P. The Lord Bishop of Norwich. Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast. Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society. William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge. William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford. CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.

PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.

SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.

The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford. The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire. The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford. The Mayor of Oxford. Sir W. R. Anson, D.C.L., Warden of All Souls College. Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine. The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy. Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry.	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.
CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord.-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, BART., D.C.L., LL.D., President of the Royal Society. LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire. Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.

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1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
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1871–72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872–76 Capt. DOUGLAS GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. DOUGLAS GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. DOUGLAS GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–98 Prof. E. A. SCHÄFER, F.R.S., and Prof. W. C. ROBERTS-AUSTEN, C.B., F.R.S.

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1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
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1890 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1890–98 G. GRIFFITH, Esq., M.A.

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Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

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1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

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1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
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1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S., F.R.S.E.	Rev. Dr. Forbes, Prof. D. Gray, Prof Tyndall.

Date and Place	Presidents	Secretaries
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.

Date and Place	Presidents	Secretaries
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh.	Dr. Hope...........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.

Date and Place	Presidents	Secretaries
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S.......	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S............ ..	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S. ...	H. S. Bell, W. Chandler Roberts, J. M. Thomson.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen ...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S.	Arthur Harden, C. A. Kohn
1897. Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place	Presidents	Secretaries
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.

[1] The subject of Geography was separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the 'Geographical and Ethnological Section'; for Presidents and Secretaries of which see page lxiv.

Date and Place	Presidents	Secretaries
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff......	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S., Sec. G.S.	J. Lomas, Prof. H. A. Miers, Clement Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.

Date and Place	Presidents	Secretaries

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxiii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lxiii.

Date and Place	Presidents	Secretaries
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham [1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh.	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

[1] The title of Section D was changed to Biology; and for the word 'Sub-section,' in the rules for conducting the business of the Sections, the word 'Department' was substituted.

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S. —*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., F.R.S. —*Dep. of Anthropol.*, Prof. W. H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.[1]	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S. —*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[2]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.

[1] The Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] Anthropology was made a separate Section, see p. lxx.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.
1888. Bath	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.

[1] Physiology was made a separate Section, see p. lxx.

[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lvii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lx.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lxi.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R.S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.

Date and Place	Presidents	Secretaries
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto ...	J. Scott-Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin......	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford......	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...........	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.

Date and Place	Presidents	Secretaries
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D.,V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, J. E. C. Munro, G. H. Sargant.
1888. Bath	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S..........	Rev. W. T. Kingsley.
1846. South'mpt'n	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingh'm	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich ...	William Cubitt, F.R.S..........	John Head, Charles Manby.

Date and Place	Presidents	Secretaries
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, F.R.S.	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	William Fairbairn, F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman. E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E.........	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	J. Brunlees, Pres. Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W B Marshall, E. Rigg.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff......	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E.	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.

SECTION H.—ANTHROPOLOGY.

1884. Montreal...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff......	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
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SECTION I.—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY).

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool...	Dr. W. H. Gaskell, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.

Date and Place	Presidents	Secretaries

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Date and Place	Presidents	Secretaries
1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
1897. Toronto ...	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison.................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S............	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron.Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S............	The present state of Photography.

Date and Place	Lecturer	Subject of Discourse
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S..........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ..	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.......	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.

Date and Place	Lecturer	Subject of Discourse
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.

Date and Place	Lecturer	Subject of Discourse
1894. Oxford	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ...	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
1897. Toronto ...	Prof. Roberts Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S.	Earthquakes and Volcanoes.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental Illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth ...	W. H. Preece	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath	Sir John Lubbock, Bart., M.P., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.

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[1] Prof. Gonner was unable to attend the Meeting.

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The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

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The Right Hon. Sir JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.S.A.
The Right Hon. Lord PLAYFAIR, G.C.B., Ph.D., LL.D., F.R.S.

PRESIDENTS OF FORMER YEARS.

The Duke of Argyll, K.G., K.T.
Lord Armstrong, C.B., LL.D.
Sir Joseph D. Hooker, K.C.S.I.
Sir G. G. Stokes, Bart., F.R.S.
Lord Kelvin, G.C.V.O., F.R.S.
Prof. A. W. Williamson, F.R.S.
Prof. Allman, M.D., F.R.S.
Sir John Lubbock, Bart., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Lord Playfair, G.C.B., F.R.S.
Sir Wm. Dawson, C.M.G., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir F. J. Bramwell, Bart., F.R.S.
Sir W. H. Flower, K.C.B., F.R.S.
Sir F. A. Abel, Bart., K.C.B., F.R.S.
Sir Wm. Huggins, K.C.B., F.R.S.
Sir Archibald Geikie, LL.D., F.R.S.
Prof. J. S. Burdon Sanderson, F.R.S.
The Marquis of Salisbury, K.G., F.R.S.
Sir Douglas Galton, K.C.B., F.R.S.
Lord Lister, D.C.L., Pres.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., F.R.S.
Prof. Michael Foster, Sec.R.S.
G. Griffith, Esq., M.A.
P. L. Sclater, Esq., Ph.D., F.R.S.
Sir Douglas Galton, K.C.B., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
Prof. A. W. Williamson, F.R.S.
A. Vernon Harcourt, Esq., F.R.S.

AUDITORS.

Professor H. McLeod, F.R.S. | Dr. J. H. Gladstone, F.R.S. | Dr. D. H. Scott, F.R.S.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1896–97. RECEIPTS.

				£	s.	d.
Balance brought forward				957	15	3
Life Compositions				490	0	0
New Annual Members' Subscriptions				336	0	0
Annual Subscriptions				580	0	0
Sale of Associates' Tickets				1369	0	0
Sale of Ladies' Tickets				873	0	0
Sale of Publications				217	18	5
Interest on Deposit at Liverpool Bank				18	16	0
Interest on Exchequer Bills				3	12	6
Dividends on Consols				200	7	4
Dividends on India 3 per Cents				104	8	0
Unexpended Balances of Grants returned :—						
Erratic Blocks Committee	£1	3	0			
Corresponding Societies Committee	0	8	10			
Calibration Committee	15	18	11			
Ethnographical Survey Committee	3	17	0			
Electrical Standards Committee	16	15	10			
				38	3	7
Income Tax returned				30	8	6
Sale of Tickets for Toronto Meeting (to June 30) :—						
Life Members	40	0	0			
Annual Members	26	0	0			
New Annual Members	24	0	0			
Associates	32	0	0			
				122	0	0
				£5341	9	7

Investments

		£	s.	d.
June 30, 1896:	Consols	7537	3	5
	India 3 per Cents	3600	0	0
		£11,137	3	5

LUDWIG MOND, HERBERT McLEOD, } *Auditors.*

from July 1, 1896, to June 30, 1897. *Cr.*

1896–97. PAYMENTS.

				£	s.	d.
Expenses of Liverpool Meeting, including Printing, Advertising, Payment of Clerks, &c.				157	8	6
Rent and Office Expenses				61	4	7
Salaries				508	15	0
Printing, Binding, &c.				1158	10	6
Payment of Grants made at Liverpool:	£	s.	d.			
Mathematical Tables	25	0	0			
Seismological Observations	100	0	0			
Abstracts of Physical Papers	100	0	0			
Calculation of Certain Integrals	10	0	0			
Electrolysis and Electro-chemistry	50	0	0			
Electrolytic Quantitative Analysis	10	0	0			
Isomeric Naphthalene Derivatives	50	0	0			
Erratic Blocks	10	0	0			
Photographs of Geological Interest	15	0	0			
Remains of the Irish Elk in the Isle of Man	15	0	0			
Table at the Zoological Station, Naples	100	0	0			
Table at the Biological Laboratory, Plymouth	9	10	8			
Zoological Bibliography and Publication	5	0	0			
Index Generum et Specierum Animalium	100	0	0			
Zoology and Botany of the West India Islands	40	0	0			
To work out Details of Observations on the Migration of Birds	40	0	0			
Climatology of Tropical Africa	20	0	0			
Ethnographical Survey	40	0	0			
Mental and Physical Condition of Children	10	0	0			
Silchester Excavation	20	0	0			
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0			
Oysters and Typhoid	30	0	0			
Physiological Applications of the Phonograph	15	0	0			
Physiological Effects of Peptone and its Precursors	20	0	0			
Fertilisation in Phæophyceæ	20	0	0			
Corresponding Societies Committee	25	0	0			
				1059	10	8
In hands of General Treasurer:						
On deposit at Liverpool	1500	0	0			
At Bank of England, Western Branch £939 7 4						
Less Cheques not presented 60 10 0						
	878	17	4			
Cash	17	3	0			
				2396	0	4
				£5341	9	7

Account

		£	s.	d.
June 30, 1897:	Consols	7537	3	5
	India 3 per Cents	3600	0	0
		£11,137	3	5

ARTHUR W. RÜCKER, *General Treasurer.*

July 9, 1897.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	The Earl Fitzwilliam, D.C.L.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, DD.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Asso-ciates	Ladies	Foreigners	Total			
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1498 0 0	1059 10 8	1897

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

REPORT OF THE COUNCIL.

Report of the Council for the Year 1896–97, *presented to the General Committee at Toronto on Wednesday, August* 18, 1897.

The Meeting at Montreal in 1884 was the first occasion on which the Association held a Meeting beyond the limits of the United Kingdom. Some of the Members then considered that it was a hazardous experiment; but the decided success of that Meeting fully justified the innovation, and when an invitation was received for holding another Meeting in the Dominion of Canada, in the University City of Toronto, the General Committee accepted it with unanimity.

The Executive Committee at Toronto have succeeded in making very complete preparations for the reception, not only of British Members of our Association, but of several Continental and numerous American Men of Science who propose to take part in our proceedings. The Council desire to record their grateful sense of the efforts made by Professor Macallum and his colleagues to render this Meeting a success, and of the liberality with which those efforts have been supported by the Dominion Government, the Government of the Province of Ontario, and the City of Toronto. The Council also desire cordially to thank the Associated Cable Companies for granting, under certain restrictions, free ocean telegraphy during the Meeting to Members coming from the United Kingdom. The Council have likewise to offer their thanks to the several Railroad and Steamship Companies which have afforded special facilities to Members.

The Council have nominated Sir Donald Smith, High Commissioner for the Dominion of Canada, the Hon. Arthur Sturgis Hardy, Premier of the Province of Ontario, and the Mayor of Toronto to be Vice-Presidents of the Association.

The Council heard with great regret that Mr. Alan Macdougall, who was appointed one of the Local Secretaries for the Toronto Meeting, had died after a long illness. Mr. Macdougall took an active part in the proceedings which gave rise to the invitation to Toronto, presented to the Association in the year 1894, at the meeting at Oxford.

The Council have been informed by Mr. Vernon Harcourt that he does not intend to offer himself for re-election as General Secretary after the Toronto Meeting. Mr. Vernon Harcourt has held the office of General Secretary for fourteen years, and the Council desire to record their sense of the invaluable services which he has constantly rendered to the Association during this period. The Council recommend that Professor Roberts-Austen, C.B., F.R.S., be appointed General Secretary in succession to Mr. Harcourt.

Professor Schäfer having informed the Council that it would be incon-

venient for him to attend the Meeting at Toronto, they have requested Professor Roberts-Austen to undertake the duties of General Secretary during the Meeting in his place.

The Council have received reports from the General Treasurer during the past year, and his accounts from July 1, 1896, to June 30, 1897, which have been audited, will be presented to the General Committee.

The Council have elected the following Foreign Men of Science, who have attended Meetings of the Association, to be Corresponding Members :—

Dr. F. Kohlrausch, Berlin.
Dr. van Rijckevorsel, Rotterdam.
Prof. E. Zacharias, Hamburg.

The following Resolutions were referred to the Council for consideration and action, if desirable :—

(1) 'That the Council be requested to take such steps as they think best to bring before the Government the question of the establishment of a National Physical Laboratory, in general accordance with the recommendations contained in the Report appended hereto, and to invite the co-operation of the Royal Society of London, the Royal Society of Edinburgh, the Royal Astronomical Society, the Physical Society, and other kindred societies, in securing its foundation.'

The Council, after considering this question, resolved to appoint a Committee to bring the proposal before the Government.

The Committee consisted of the following Members :—

The President of the Royal Society	Royal Society.
Lord Kelvin	
Lord Rayleigh	
Mr. Francis Galton	
Professor A. W. Rücker	
Sir Douglas Galton	British Association
Sir H. E. Roscoe	
Mr. R. T. Glazebrook	
Professor Oliver Lodge	
Professor A. Schuster	
Professor G. F. Fitzgerald	Royal Irish Academy.
The Astronomer-Royal	Royal Astronomical Society.
Mr. A. Vernon-Harcourt	Chemical Society.
Captain Abney	Physical Society.
Dr. John Hopkinson	Institution of Civil Engineers.
Professor W. E. Ayrton	Institution of Electrical Engineers.

The Royal Society of Edinburgh was also represented by Lord Kelvin.

The Council have been informed that, at the request of the Committee, a Deputation waited upon Lord Salisbury, and have recently learned that a Committee has been appointed by the Treasury : 'To consider and report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation ; for the construction and preservation of standards of measurements and for the systematic determination of physical constants and numerical "data" useful for scientific and industrial purposes, and to report whether the work of such an institution, if established, could be associated with any testing or standardizing work already performed wholly or partly at the public cost.'

The following will be the members of the Committee :—

The Lord Rayleigh, D.C.L., F.R.S. (*Chairman*).
Sir Courtenay Boyle, K.C.B.
Sir Andrew Noble, K.C.B., F.R.S.
Sir John Wolfe Barry, K.C.B., F.R.S.
W. C. Roberts-Austen, Esq., C.B., F.R.S.
Robert Chalmers, Esq., of the Treasury.
A. W. Rücker, Esq., D.Sc., F.R.S.
Alexander Siemens, Esq.
T. E. Thorpe, Esq., F.R.S.

(2) 'That it is of urgent importance to press upon the Government the necessity of establishing a Bureau of Ethnology for Greater Britain, which, by collecting information with regard to the native races within and on the borders of the Empire, will prove of immense value to science and to the Government itself.'

The Council referred this question to a Committee consisting of the President and General Officers, with Sir John Evans, Sir John Lubbock, Mr. C. H. Read, and Professor Tylor. The Report of the Committee was as follows :—

'A central establishment in England, to which would come information with regard to the habits, beliefs, and methods of government of the primitive peoples now existing would be of great service to science, and of no inconsiderable utility to the Government.

'1. The efforts of the various societies which have, during the last twenty years, devoted themselves to collecting and publishing ethnological information have necessarily produced somewhat unequal, and therefore unsatisfactory, results. Such societies had, of course, to depend upon the reports of explorers, who usually travelled for another purpose than that in which the societies were interested ; and such reports were naturally unsystematic, the observers being mostly untrained in the science. Again, whole regions would be unrepresented in the transactions of the societies, perhaps from the absence of the usual attractions of travellers, *e.g.* big game or mineral riches. This has been to some extent corrected, at least as to the systematic nature of the reports, by the publication of "Anthropological Notes and Queries" by the Anthropological Institute, with the help of the British Association.

'If it be admitted that the study of the human race is an important branch of science, no further argument is needed to commend the gathering of facts with regard to the conditions under which aboriginal races now live, and, if this work is worth doing, it should be done without delay. With the exception, perhaps, of the negro, it would seem that none of the lower races are capable of living side by side with whites. The usual result of such contact is demoralisation, physical decline, and steady diminution of numbers ; in the case of the Tasmanians, entire disappearance. Such will probably soon be the fate of the Maories, the Andamanese, the North American Indians, and the blacks of Australia. While these exist it is possible to preserve their traditions and folk-lore, and to record their habits of life, their arts, and the like, and such direct evidence is necessarily more valuable than accounts filtered through the recollection of the most intelligent white man.

'It is scarcely necessary to enlarge upon this point, as no one will seriously question the value to science of such information. But it does seem necessary to urge that no time be lost.

'2. As to the benefit to the Government of these inquiries, the history of our relations with native tribes in India and the Colonies is rich in examples. No one who has read of the ways of the African can doubt

that a thorough study of his character, his beliefs and superstitions, is a necessity for those who have to deal with him. And what is true of the natives of Africa is also true, in a greater or less degree, of all uncivilised races. Their ideas of common things and common acts are so radically different from those of civilised man that it is impossible for him to understand them without a special training.

'Even in dealing with the highly civilised natives of India it is most necessary that an inquirer should be familiar with their religion, and with the racial prejudices which the natives of India possess in common with other civilised nations.

'A training in knowledge of native habits is now gone through by our officers, traders, and missionaries on the spot; and by experience—sometimes dearly bought—they, after many failures, learn how to deal with the natives. By the establishment of such a Bureau as is here advocated much might be done to train our officers before they go out, as is now done by the Dutch Government, who have a handbook and a regular course of instruction as to the life, laws, religion, &c., of the inhabitants of the Dutch Indies. The experience thus gained would then mature rapidly, and they would become valuable servants to the State more quickly.

'The collecting of the necessary information for the Bureau could be done with but little expense and with a very small staff only, if the scheme were recognised and forwarded by the Government. If instructions were issued, for instance, by the Colonial Office, the Foreign Office, the Admiralty, and the Intelligence Branch of the War Office, to the officers acting under each of these departments, not only that they were at liberty to conduct these inquiries, but that credit would be given to them officially for good work in this direction, there is little doubt that many observers qualified by their previous training would at once put themselves and their leisure at the disposal of the Bureau.

'The Bureau itself, the central office, would be of necessity in London—in no other place could it properly serve its purpose—and preferably, for the sake of economy and official control, it should be under the administration of some existing Government office. But the various interests involved make it somewhat difficult to recommend where it should be placed. The Colonial Office would obviously present some advantages. The British Museum has been suggested, with good reason, and there appears to be no insuperable difficulty if the Trustees are willing to undertake the responsibility of controlling such a department.

'The staff would not be numerous. A Director accustomed to deal with ethnological matter would necessarily direct the conduct of the inquiries, and until the material assumed large proportions, two or three clerks would probably suffice. If the value of the results were considered to justify it, the increase of the area of operations over the world would probably call for additional assistance after the Bureau had been at work for a few years.

'The Bureau of Ethnology in the United States aims chiefly at publishing its reports, but its area is limited to America. The scope of the present proposal is so much wider that the Committee think it better not to deal with the question of publication at present.

'If this report be adopted by the Council it will be necessary to approach the Government, and impress upon them the importance of having such an organisation for carrying out these recommendations.

For this purpose a Deputation should be appointed, and it would be well to invite the Council of the Anthropological Institute to appoint two members.'

The Council resolved that the Trustees of the British Museum be requested to consider whether they could allow the proposed Bureau to be established in connection with the Museum: and if they are unable to sanction this proposal, that the authorities of the Imperial Institute be requested to undertake its establishment.

The matter is now under the consideration of the Trustees of the British Museum.

The Report of the Corresponding Societies Committee for the past year, together with the list of the Corresponding Societies and the titles of the more important papers, and especially those referring to Local Scientific Investigations, published by those Societies during the year ending June 1, 1897, has been received.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola (*Chairman*), Sir Douglas Galton, Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, Professor T. G. Bonney, Mr. T. V. Holmes, Mr. Cuthbert Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, and Professor W. W. Watts is hereby nominated for reappointment by the General Committee.

The Council nominate Professor R. Meldola, F.R.S., Chairman, and Mr. John Hopkinson, Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Toronto.

In accordance with the regulations the retiring Members of the Council will be :—

Anderson, Sir W.
Foxwell, Professor.
Lodge, Professor O. J.
Vines, Professor.
Ward, Professor Marshall.

The Council recommend the re-election of the other ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list :—

Boys, C. Vernon, Esq., F.R.S.
Creak, Captain E. W., R.N., F.R.S.
*Darwin, F., Esq., F.R.S.
Edgeworth, Professor F. Y., M.A.
*Fremantle, The Hon. Sir C. W., K.C.B.
*Halliburton, Professor W. D., F.R.S.
Harcourt, Professor L. F. Vernon, M.A., M.Inst.C.E.
Herdman, Professor W. A., F.R.S.
Hopkinson, Dr. J., F.R.S.
Horsley, Victor, Esq., F.R.S.
Marr, J. E., Esq., F.R.S.
Meldola, Professor R., F.R.S.
Poulton, Professor E. B., F.R.S.
Preece, W. H., Esq., C.B., F.R.S.
Ramsay, Professor W., F.R.S.
Reynolds, Professor J. Emerson, M.D., F.R.S.
Shaw, W. N., Esq., F.R.S.
Symons, G. J., Esq., F.R.S.
Teall, J. J. H., Esq., F.R.S.
Thiselton-Dyer, W. T., Esq., C.M.G., F.R.S.
*Thompson, Professor S. P., F.R.S.
Thomson, Professor J. M., F.R.S.
Tylor, Professor E. B., F.R.S.
Unwin, Professor W. C., F.R.S.
*White, Sir W. H., K.C.B., F.R.S.

It was resolved last year, at the Liverpool Meeting, that two meetings of the General Committee shall be held at Toronto, and that an adjourned meeting shall be held in London at the beginning of November, for the election of the President, Officers, and Council for 1897–8, and for fixing the date of the Meeting in that year. The Council have arranged that the adjourned meeting shall be held at the Rooms of the Royal Society, Burlington House, on Friday, November 5, at 3 P.M.

At this meeting an invitation which has been received from the Corporation of Glasgow to hold the Annual Meeting of the Association in 1901 in that city will be presented to the General Committee.

The Council, acting on behalf of the Association, have presented to Her Majesty the Queen the following Address of Congratulation on the completion of the sixtieth year of her reign :—

To the QUEEN'S MOST EXCELLENT MAJESTY.

May it please your Majesty,—

We, your Majesty's most dutiful and loyal subjects, the President and Council of the British Association for the Advancement of Science, desire most respectfully to approach your Majesty with the expression of our sincere and heartfelt congratulations on the completion of the sixtieth year of your Majesty's auspicious reign.

During that reign, which has exceeded in length that of any of your illustrious predecessors, the increase in prosperity of your Majesty's subjects has been unparalleled.

This advance in the welfare of the nation has been in no small degree due to the astonishing progress of science during this period, and its application to the details of daily life; and we thankfully recognise the interest constantly displayed both by your Majesty and by members of your Royal Family in the promotion of science. Of this, the acceptance by His Royal Highness the late lamented Prince Consort of the Presidency of this Association at Aberdeen, in the year 1859, was a conspicuous illustration.

That your Majesty's subjects in all parts of the globe are united in their efforts to promote the advancement of knowledge is evinced by the fact that the Association holds its annual meeting this year at Toronto, on the invitation of one of the principal Dependencies of your Empire, the great Dominion of Canada.

There, as here, the Members of the Association will ever pray that your Majesty may long be spared to rule over a contented, grateful, and united Empire.

Signed on behalf of the Council,

LISTER,
President.

June 23, 1897.

The Address was laid before the Queen by the Home Secretary, who has informed the Council that Her Majesty was pleased to receive the same very graciously.

Committees appointed by the General Committee at the Toronto Meeting in August 1897.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Professor G. Carey Foster. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and Oliver J. Lodge, Lord Rayleigh, Dr. John Hopkinson, Dr. A. Muirhead, Mr. W. H. Preece, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald and J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Mr. E. H. Griffiths, Professor A. W. Rücker, and Professor A. G. Webster.	75 0 0
Seismological Observations.	*Chairman.*—Mr. G. J. Symons. *Secretaries.*—Dr. C. Davison and Professor J. Milne. Lord Kelvin, Professor W. G. Adams, Dr. J. T. Bottomley, Sir F. J. Bramwell, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Mr. G. F. Deacon, Professor J. A. Ewing, Professor C. G. Knott, Professor G. A. Lebour, Professor R. Meldola, Professor J. Perry, Professor J. H. Poynting, Dr. Isaac Roberts, Dr. G. M. Dawson, Professor T. G. Bonney, Mr. C. V. Boys, Professor H. H. Turner, and Mr. M. Walton Brown.	75 0 0
To assist the Physical Society in bringing out Abstracts of Physical Papers.	*Chairman.*—Dr. E. Atkinson. *Secretary.*—Professor A. W. Rücker.	100 0 0
To co-operate with Professor Karl Pearson in the Calculation of certain Integrals.	*Chairman.*—Rev. Robert Harley. *Secretary.*—Dr. A. R. Forsyth. Dr. J. W. L. Glaisher, Professor A. Lodge, and Professor Karl Pearson.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
The present state of our Knowledge in Electrolysis and Electro-chemistry.	*Chairman.*—Mr. W. N. Shaw. *Secretary.*—Mr. W. C. D. Whetham. Rev. T. C. Fitzpatrick and Mr. E. H. Griffiths.	35 0 0
To establish a Meteorological Observatory on Mount Royal, Montreal.	*Chairman.*—Professor Callendar. *Secretary.*—Professor C. H. McLeod. Professor F. Adams and Mr. R. F. Stupart.	50 0 0
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Sir J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.	20 0 0
The Electrolytic Methods of Quantitative Analysis.	*Chairman.*—Professor J. Emerson Reynolds. *Secretary.*—Dr. C. A. Kohn. Professor Frankland, Professor F. Clowes, Dr. Hugh Marshall, Mr. A. E. Fletcher, and Professor W. Carleton Williams.	12 0 0
The Action of Light upon Dyed Colours.	*Chairman.*—Dr. T. E. Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. W. H. Perkin, Professor W. J. Russell, Captain Abney, Professor W. Stroud, and Professor R. Meldola.	8 0 0
The Promotion of Agriculture: to report on the means by which in various Countries Agriculture is advanced by research, by special Educational Institutions, and by the dissemination of information and advice among agriculturists.	*Chairman.*—Sir John Evans. *Secretary.*—Professor H. E. Armstrong. Professor M. Foster, Professor Marshall Ward, Sir J. H. Gilbert, Right Hon. J. Bryce, Professor J. W. Robertson, Dr. W. Saunders, Professor Mills, Professor J. Mavor, Professor R. Warington, Professor Poulton, and Mr. S. U. Pickering.	5 0 0
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Professor E. Hull. *Secretary.*—Prof. P. F. Kendall. Professor T. G. Bonney, Mr. C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Mr. J. Horne, Mr. Dugald Bell, Mr. F. M. Burton, and Mr. J. Lomas.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To consider a project for investigating the Structure of a Coral Reef by Boring and Sounding.	*Chairman.*—Professor T. G. Bonney. *Secretary.*—Professor W. J. Sollas. Sir Archibald Geikie, Professors J. W. Judd, C. Lapworth, A. C. Haddon, Boyd Dawkins, G. H. Darwin, S. J. Hickson, and Anderson Stuart, Admiral Sir W. J. L. Wharton, Drs. H. Hicks, J. Murray, W. T. Blanford, C. Le Neve Foster, and H. B. Guppy, Messrs. F. Darwin, H. O. Forbes, G. C. Bourne, Sir A. R. Binnie, Dr. J. W. Gregory, and Mr. J. C. Hawkshaw.	40 0 0
To explore certain Caves in the Neighbourhood of Singapore, and to collect their living and extinct Fauna. [Last year's grant of 40*l.* unexpended.]	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. H. N. Ridley. Dr. R. Hanitsch, Mr. Clement Reid, and Mr. A. Russel Wallace.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, R. H. Tiddeman, J. J. H. Teall, J. G. Goodchild, H. Coates, and C. V. Crook.	10 0 0
To study Life-zones in the British Carboniferous Rocks. [Balance of last year's grant.]	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Mr. E. J. Garwood. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Dr. Wheelton Hind, Dr. G. J. Hinde, Mr. P. F. Kendall, Mr. J. W. Kirkley, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. G. H. Morton, Professor H. A. Nicholson, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	
To examine the Conditions under which remains of the Irish Elk are found in the Isle of Man. [Balance of last year's grant.]	*Chairman.*—Professor W. Boyd Dawkins. *Secretary.*—Mr. P. C. Kermode. His Honour Deemster Gill, Mr. G. W. Lamplugh, and Canon E. B. Savage.	
To ascertain the Age and Relations of the Rocks in which Secondary Fossils have been found near Moreseat, Aberdeenshire.	*Chairman.*—Mr. T. F. Jamieson. *Secretary.*—Mr. J. Milne. Mr. A. J. Jukes-Browne.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To further investigate the Fauna and Flora of the Pleistocene Beds in Canada.	*Chairman.*—Sir J. W. Dawson. *Secretary.*—Professor A. P. Coleman. Professor D. P. Penhallow, Dr. H. Ami, and Mr. G. W. Lamplugh.	20 0 0
To enable Mr. H. M. Vernon to investigate the development of Echinoderm larvæ experimentally, or, failing this, to appoint some other competent investigator to carry on a definite piece of work at the Zoological Station at Naples.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. Percy Sladen. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor S. J. Hickson, Mr. A. Sedgwick, Professor W. C. M'Intosh, and Mr. W. E. Hoyle.	100 0 0
To enable Profesor S. J. Hickson to study the fertilisation of Alcyonium, Mr. C. D. Scott to investigate the physiology of secretion in Tunicata, and Messrs. A. H. Church and G. Brebner to study the reproduction of marine Algæ, or, in default of these, to appoint some other competent Naturalist to do a definite piece of work at the Plymouth Marine Laboratory.	*Chairman.*—Mr. G. C. Bourne. *Secretary.* — Professor E. Ray Lankester. Professor Sydney H. Vines, Mr. A. Sedgwick, and Professor W. F. R. Weldon.	20 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. F. A. Bather. Dr. P. L. Sclater, Dr. H. Woodward, Rev. T. R. R. Stebbing, Mr. R. McLachlan, and Mr. W. E. Hoyle.	100 0 0
The Biology of the Lakes of Ontario.	*Chairman.*—Professor L. C. Miall. *Secretary.*—Professor R. Ramsay Wright. Senator Allan, Dr. G. M. Dawson, Professor W. H. Ellis, Professor E. E. Prince, and Professor John Macoun.	75 0
Healthy and unhealthy Oysters.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor R. Boyce. Mr. G. C. Bourne, Professor C. S. Sherrington, and Dr. C. Kohn.	30 0 0
Climatology of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Mr. H. N. Dickson. Sir John Kirk, Dr. H. R. Mill, and Mr. G. J. Symons.	10 0 0
State Monopolies in other Countries.	*Chairman.*—Professor H. Sidgwick. *Secretary.*—Mr. H. Higgs. Mr. W. M. Acworth, the Rt. Hon. L. H. Courtney, and Professor H. S. Foxwell.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
Future Dealings in Raw Produce.	*Chairman.*—Mr. L. L. Price. *Secretaries.*—Professor Gonner and Mr. E. Helm. Mr. Hugh Bell, Major P. G. Craigie, Professor W. Cunningham, Professor Edgeworth, Mr. R. H. Hooker, and Mr. H. R. Rathbone.	10 0 0
To consider means by which better practical effect can be given to the Introduction of the Screw Gauge proposed by the Association in 1884.	*Chairman.*—Mr. W. H. Preece. *Secretary.*—Mr. W. A. Price. Lord Kelvin, Sir F. J. Bramwell, Sir H. Trueman Wood, Maj.-Gen. Webber, Mr. R. E. Crompton, Mr. A. Stroh, Mr. A. Le Neve Foster, Mr. C. J. Hewitt, Mr. G. K. B. Elphinstone, Mr. T. Buckney, Col. Watkin, Mr. E. Rigg, and Mr Conrad W. Cooke.	20 0 0
The Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. Cuthbert E. Peek. Dr. G. M. Dawson, Mr. R. G. Haliburton, Mr. David Boyle, and Hon. G. W. Ross.	75 0 0
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, General Pitt-Rivers, Sir John Evans, and Mr. Arthur J. Evans.	37 10 0
To organise an Ethnographical Survey of the United Kingdom. [And unexpended balance in hand.]	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. E. Sidney Hartland. Mr. Francis Galton, Dr. J. G. Garson, Professor A. C. Haddon, Dr. Joseph Anderson, Mr. J. Romilly Allen, Dr. J. Beddoe, Mr. W. Crooke, Professor D. J. Cunningham, Professor W. Boyd Dawkins, Mr. Arthur J. Evans, Dr. H. O. Forbes, Mr. F. G. Hilton Price, Sir H. Howorth, Professor R. Meldola, General Pitt-Rivers, and Mr. E. G. Ravenstein.	25 0 0
To co-operate with the Silchester Excavation Fund Committee in their Explorations	*Chairman.*—Mr. A. J. Evans. *Secretary.*—Mr. John L. Myres Mr. E. W. Brabrook.	7 10 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To organise an Ethnological Survey of Canada.	*Chairman.*—Dr. George Dawson. *Secretary.*—Dr. George Dawson. Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Dr. J. G. Bourinot, Abbé Cuoq, Mr. B. Sulte, Abbé Tanquay, Mr. C. Hill-Tout, Mr. David Boyle, Rev. Dr. Scadding, Rev. Dr. J. Maclean, Dr. Nerée Beauchemin, Rev. Dr. G. Patterson, Professor D. P. Penhallow, Mr. C. N. Bell, Hon. G. W. Ross, Professor J. Mavor, and Mr. A. F. Hunter.	75 0 0
The Anthropology and Natural History of Torres Straits.	*Chairman.*—Sir W. Turner. *Secretary.*—Professor A. C. Haddon. Professor M. Foster, Dr. J. Scott Keltie, Professor L. C. Miall, and Professor Marshall Ward.	125 0 0
To investigate the changes which are associated with the functional activity of Nerve Cells and their peripheral extensions.	*Chairman.*—Dr. W. H. Gaskell. *Secretary.*—Dr. A. Waller. Professor Burdon Sanderson, Professor M. Foster, Professor E. A. Schäfer, Professor J. G. McKendrick, Professor W. D. Halliburton, Professor J. B. Haycraft, Professor F. Gotch, Professor C. S. Sherrington, Dr. J. N. Langley, Dr. Mann, and Professor A. B. Macallum.	100 0 0
Fertilisation in Phæophyceæ.	*Chairman.*—Professor J. B. Farmer. *Secretary.*—Professor R. W. Phillips. Professor F. O. Bower and Professor Harvey Gibson.	15 0 0
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Professor R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Mr. Cuthbert Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, and Professor W. W. Watts.	25 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
To confer with British and Foreign Societies publishing Mathematical and Physical Papers as to the desirability of securing Uniformity in the size of the pages of their Transactions and Proceedings.	*Chairman.*—Professor S. P. Thompson. *Secretary.*—Mr. J. Swinburne. Prof. G. H. Bryan, Mr. C. V. Burton, Mr. R. T. Glazebrook, Professor A. W. Rücker, and Dr. G. Johnstone Stoney.
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Mr. John Murray, Dr. A. Buchan, and Professor R. Copeland.
To confer with the Astronomer Royal and the Superintendents of other Observatories with reference to the Comparison of Magnetic Standards with a view of carrying out such comparison.	*Chairman.*—Professor A. W. Rücker. *Secretary.*—Mr. W. Watson. Professor A. Schuster and Professor H. H. Turner.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Dr. C. Chree. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Professor A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.
The Collection and Identification of Meteoric Dust.	*Chairman.*—Mr. John Murray. *Secretary.*—Mr. John Murray. Professor A. Schuster, Lord Kelvin, the Abbé Renard, Dr. A. Buchan, Dr. M. Grabham, Mr. John Aitken, Mr. L. Fletcher, Mr. A. Ritchie Scott.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Professor Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Professor Edward Hull, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, Professor Michie Smith, and Professor H. L. Callendar.
That Professor S. P. Thompson and Professor A. W. Rücker be requested to draw up a Report on the State of our Knowledge concerning Resultant Tones.	—
The Application of Photography to the Elucidation of Meteorological Phenomena.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. A. W. Clayden. Professor R. Meldola, Mr. John Hopkinson, and Mr. H. N. Dickson.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
For Calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.	*Chairman.*—Lord Kelvin. *Secretary.*—Lieut.-Colonel Allan Cunningham. Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, Major P. A. Macmahon, and Professor A. Lodge.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Sir G. G. Stokes. *Secretary.*—Professor H. McLeod. Professor A. Schuster, Dr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain W. de W. Abney, Dr. C. Chree, Mr. G. J. Symons, Mr. W. E. Wilson, and Professor A. A. Rambaut.
That Mr. E. T. Whittaker be requested to draw up a Report on the Planetary Theory.	—
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Professor Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Carbohydrates of Barley Straw.	*Chairman.*—Professor R. Warington. *Secretary.*—Mr. C. F. Cross. Mr. Manning Prentice.
The Teaching of Natural Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. George Gladstone, Mr. W. R. Dunstan, Sir J. Lubbock, Sir Philip Magnus, Sir H. E. Roscoe, and Dr. Silvanus P. Thompson.
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Rev. Professor T. Wiltshire. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, Professor H. G. Seeley, and Mr. H. Woods.
The Collection, Preservation, and Systematic Registration of Canadian Photographs of Geological Interest.	*Chairman.*—Professor A. P. Coleman. *Secretary.*—Mr. Parks. Professor A. B. Willmott, Professor F. D. Adams, Mr. J. B. Tyrrell, and Professor W. W. Watts.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The Investigation of the African Lake Fauna by Mr. J. E. Moore.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Professor G. B. Howes. Dr. John Murray, Professor E. Ray Lankester, and Professor W. A. Herdman.
To continue the investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Mr. O. Salvin, Dr. P. L. Sclater, and Mr. Edgar A. Smith.
The Necessity for the immediate investigation of the Biology of Oceanic Islands.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Professor A. C. Haddon. Mr. G. C. Bourne, Dr. H. O. Forbes, Professor W. A. Herdman, Professor S. J. Hickson, Dr. John Murray, Professor A. Newton, and Mr. A. E. Shipley.
To report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and to take steps to investigate ascertained deficiencies in the Fauna and Flora.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. G. Murray. Mr. W. Carruthers, Dr. A. C. Günther, Dr. D. Sharp, Mr. F. Du Cane Godman, and Professor A. Newton.
To work out the details of the Observations on the Migration of Birds at Lighthouses and Lightships, 1880–87.	*Chairman.*—Professor A. Newton. *Secretary.*—Mr. John Cordeaux. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Mr. W. E. Clarke, Rev. E. P. Knubley, and Dr. H. O. Forbes.
Zoological Bibliography and Publication.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. F. A. Bather. Professor W. A. Herdman, Mr. W. E. Hoyle, Dr. P. Lutley Sclater, Mr. Adam Sedgwick, Dr. D. Sharp, Mr. C. D. Sherborn, Rev. T. R. R. Stebbing, and Professor W. F. R. Weldon.
Anthropometric Measurements in Schools.	*Chairman.*—Professor A. Macalister. *Secretary.*—Professor B. Windle. Mr. E. W. Brabrook, Professor J. Cleland, and Dr. J. G. Garson.
To co-operate with the Committee appointed by the International Congress of Hygiene and Demography in the investigation of the Mental and Physical Condition of Children.	*Chairman.*—Sir Douglas Galton. *Secretary.*—Dr. Francis Warner. Mr. E. W. Brabrook, Dr. J. G. Garson, and Mr. White Wallis.
Linguistic and Anthropological Characteristics of the North Dravidians—the Uran*ws*.	*Chairman.*—Mr. E. Sidney Hartland. *Secretary.*—Mr. Hugh Raynbird, jun. Professor A. C. Haddon and Mr. J. L. Myres.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The physiological effects of Peptone and its Precursors when introduced into the circulation.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor W. H. Thompson. Professor R. Boyce and Professor C. S. Sherrington.
The Establishment of a Biological Station in the Gulf of St. Lawrence.	*Chairman.*—Professor E. E. Prince. *Secretary.*—Professor D. P. Penhallow. Professor J. Macoun, Dr. T. Wesley Mills, Professor E. Macbride, Dr. A. B. Macallum, and Mr. W. T. Thiselton-Dyer.

Communications ordered to be printed in extenso.

A Report on 'The Historical Development of Abelian Functions,' by Dr. Harris Hancock.

A Paper by Professor Callendar and Professor J. T. Nicolson on 'A New Apparatus for Studying the Rate of Condensation of Steam on a Metal Surface at different Temperatures and Pressures.'

The Table of Measurements made by Professor Martens for the Committee on 'Calibration of Instruments in Engineering Laboratories.'

A Report by Dr. Henry M. Ami on 'The State of the Principal Museums in Canada and Newfoundland.'

Resolutions referred to the Council for consideration, and action if desirable.

That, in view of the facts (1) that a Committee of Astronomers appointed by the Royal Society of London, in consequence of a communication from the Royal Society of Canada, has recently considered the matter, and has arrived at the conclusion that no change can now be introduced in the Nautical Almanac for 1901, and (2) that few English Astronomers are attending the Toronto Meeting of the Association,

Resolved: That the Committees of Sections A and E are not in a position to arrive at any definite conclusion with respect to the Unification of Time; but they think it desirable to call the attention of the Council to the subject, in which the interests of Mariners are deeply involved, with the view of their taking such action in the matter as may seem to them to be desirable.

That the Council be requested to consider the desirability of approaching the Government with a view to the establishment in Britain of experimental agricultural stations similar in character to those which are producing such satisfactory results in Canada.

That a Committee be appointed to report to the Council whether, and, if so, in what form, it is desirable to bring before the Canadian Government the necessity for a Hydrographic Survey of Canada, and that the following be the Committee:—

Professor A. Johnson (Chairman and Secretary), Lord Kelvin, Professor G. H. Darwin, Admiral Sir W. J. L. Wharton, Professor Bovey, and Professor Macgregor.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Toronto Meeting, August 1897. The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Foster, Professor Carey—Electrical Standards	75	0	0
*Symons, Mr. G. J.—Seismological Observations	75	0	0
*Atkinson, Dr. E.—Abstracts of Physical Papers	100	0	0
*Harley, Rev. R.—Calculation of Certain Integrals	20	0	0
*Shaw, Mr. W. N.—Electrolysis and Electro-chemistry	35	0	0
Callendar, Prof.—Meteorological Observatory at Montreal	50	0	0

Chemistry.

*Roscoe, Sir H. E.—Wave-length Tables of the Spectra of the Elements	20	0	0
*Reynolds, Professor J. Emerson.—Electrolytic Quantitative Analysis	12	0	0
*Thorpe, Dr. T. E.—Action of Light upon Dyed Colours	8	0	0
Evans, Sir J.—Promotion of Agriculture	5	0	0

Geology.

*Hull, Professor E.—Erratic Blocks	5	0	0
*Bonney, Professor T. G.—Investigation of a Coral Reef	40	0	0
*Flower, Sir W. H.—Fauna of Singapore Caves (Unexpended balance in hand, 40*l.*)	—		
*Geikie, Professor J.—Photographs of Geological Interest	10	0	0
*Marr, Mr. J. E.—Life-zones in British Carboniferous Rocks (Unexpended balance in hand)	—		
Dawkins, Professor W. Boyd.—Remains of the Irish Elk in the Isle of Man (Unexpended balance in hand)	—		
*Jamieson, Mr. T. F.—Age of Rocks near Moreseat	10	0	0
Dawson, Sir J. W.—Pleistocene Fauna and Flora in Canada	20	0	0

Zoology.

*Herdman, Professor W. A.—Table at the Zoological Station, Naples	100	0	0
*Bourne, Mr. G. C.—Table at the Biological Laboratory, Plymouth	20	0	0
*Flower, Sir W. H.—Index Generum et Specierum Animalium	100	0	0
Miall, Prof.—Biology of the Lakes of Ontario	75	0	0
*Herdman, Prof. W. A.—Healthy and Unhealthy Oysters	30	0	0
Carried forward	£810	0	0

* Reappointed.

	£	s.	d.
Brought forward	810	0	0
Geography.			
*Ravenstein, Mr. E. G.—Climatology of Tropical Africa	10	0	0
Economic Science and Statistics.			
Sidgwick, Prof. H.—State Monopolies in other Countries	15	0	0
Price, Mr. L. L.—Future Dealings in Raw Produce	10	0	0
Mechanical Science.			
*Preece, Mr. W. H.—Small Screw Gauge	20	0	0
Anthropology.			
*Tylor, Professor E. B.—North-Western Tribes of Canada	75	0	0
*Munro, Dr. R.—Lake Village at Glastonbury	37	10	0
*Brabrook, Mr. E. W.—Ethnographical Survey (and unexpended balance in hand)	25	0	0
Evans, Mr. A. J.—Silchester Excavation	7	10	0
*Dawson, Dr. G. M.—Ethnological Survey of Canada	75	0	0
Turner, Sir W.—Anthropology and Natural History of Torres Strait	125	0	0
Physiology.			
Gaskell, Dr. W. H.—Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Botany.			
Farmer, Professor J. B.—Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies.			
*Meldola, Professor R.—Preparation of Report	25	0	0
	£1,350	0	0

* Reappointed.

The Annual Meeting in 1898.

The Annual Meeting of the Association in 1898 will commence on Wednesday, September 7, at Bristol.

The Annual Meeting in 1899.

The Annual Meeting of the Association in 1899 will commence on Wednesday, September 13, at Dover.

The Annual Meeting in 1901.

The Annual Meeting of the Association in 1901 will be held at Glasgow.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	6
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells ...	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology.........1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu......	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals......	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh.................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall .	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York...........	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay.............................	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers..........................	11	7	6
Anemometers' Repairs.........	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854 £75 0 0; 1855 £500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations ...	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed ...	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl Series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture...	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations ...	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature ...	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature ...	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards...........	25	0	0
High Insulation Key...........	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record..............	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements..............	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record..............	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters.........................	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise..............	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives..........................	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters..........................	15	0	0
Geological Record...............	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station...	25	0	0
Elimination of Nitrogen by Bodily Exercise...............	38	3	3
Exploration of Mount Kilima-njaro......................	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges.....................	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust.................	20	0	0
Meteorological Observatory at Chepstow......................	25	0	0
Tidal Observations..............	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa.....................	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters..........................	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds..............	20	0	0
Coagulation of Blood...........	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory.........	150	0	0
Electrical Standards...........	2	6	4
Magnetic Observations.........	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives...........................	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington...	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford...	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society ...	50	0	0
Pliocene Fauna of St. Erth...	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station ...	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei ...	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development...........	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands..........................	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory.........	50	0	0
Electrical Standards............	75	0	0
Electrolysis.......................	20	0	0
Surface Water Temperature...	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record..............	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations ...	100	0	0
Flora of China	25	0	0
Naples Zoological Station ...	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands..........................	100	0	0
Geology and Geography of Atlas Range...	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath......	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards...........	12	17	0
Electrolysis	5	0	0
Electro-optics.....................	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters..........................	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton ...	25	0	0
Botanical Station at Peradeniya....	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel...	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire ...	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis ...	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands...	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory...	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis ...	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave	5	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart	10	0	0
Exploration in Abyssinia	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut	50	0	0
Calibration and Comparison of Measuring Instruments	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1,104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electro-chemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1,059	10	8

General Meetings.

On Wednesday, August 18, at 8 P.M., in the Massey Hall, Toronto, Lord Lister, M.D., D.C.L., LL.D., Pres.R.S., resigned the office of President to Sir John Evans, K.C.B., D.C.L., LL.D., Treasurer of the Royal Society, who took the Chair, and delivered an Address, for which see page 3.

On Thursday, August 19, at 8.30 P.M., a Soirée took place in the Legislative Buildings.

On Friday, August 20, at 8.30 P.M., in the Massey Hall, Professor Roberts-Austen, C.B., F.R.S., delivered a discourse on 'Canada's Metals.'

On Monday, August 23, at 8.30 P.M., in the Massey Hall, Professor John Milne, F.R.S., delivered a discourse on 'Earthquakes and Volcanoes.'

On Tuesday, August 24, at 8.30 P.M., a Soirée took place in the University Buildings.

On Wednesday, August 25, at 2.30 P.M., in the Gymnasium, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Bristol. [The Meeting is appointed to commence on Wednesday, September 7, 1898.]

Erratum.

Report 1896, page 867, line 4, *for* Professor GONNER, *read* Mr. L. L. PRICE.

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR JOHN EVANS, K.C.B.

D.C.L., LL.D., Sc.D., Treas.R.S., V.P.S.A., For.Sec.G.S.

Correspondant de l'Institut de France, &c.

PRESIDENT.

Once more has the Dominion of Canada invited the British Association for the Advancement of Science to hold one of the annual meetings of its members within the Canadian territory; and for a second time has the Association had the honour and pleasure of accepting the proffered hospitality.

In doing so, the Association has felt that if by any possibility the scientific welfare of a locality is promoted by its being the scene of such a meeting, the claims should be fully recognised of those who, though not dwelling in the British Isles, are still inhabitants of that Greater Britain whose prosperity is so intimately connected with the fortunes of the Mother Country.

Here, especially, as loyal subjects of one beloved Sovereign, the sixtieth year of whose beneficent reign has just been celebrated with equal rejoicing in all parts of her Empire; as speaking the same tongue, and as in most instances connected by the ties of one common parentage, we are bound together in all that can promote our common interests.

There is, in all probability, nothing that will tend more to advance those interests than the diffusion of science in all parts of the British Empire, and it is towards this end that the aspirations of the British Association are ever directed, even if in many instances the aim may not be attained.

We are, as already mentioned, indebted to Canada for previous hospitality, but we must also remember that, since the time when we last assembled on this side of the Atlantic, the Dominion has provided the

Association with a President, Sir William Dawson, whose name is alike well known in Britain and America, and whose reputation is indeed world-wide. We rejoice that we have still among us the pioneer of American geology, who among other discoveries first made us acquainted with the 'Air-breathers of the Coal,' the terrestrial or more properly arboreal Saurians of the New Brunswick and Nova Scotia Coal-measures.

On our last visit to Canada, in 1884, our place of assembly was Montreal, a city which is justly proud of her McGill University; to-day we meet within the buildings of another of the Universities of this vast Dominion—and in a city, the absolute fitness of which for such a purpose must have been foreseen by the native Indian tribes when they gave to a small aggregation of huts upon this spot the name of Toronto—'the place of meetings.'

Our gathering this year presents a feature of entire novelty and extreme interest, inasmuch as the sister Association of the United States of America,—still mourning the loss of her illustrious President, Professor Cope,—and some other learned societies, have made special arrangements to allow of their members coming here to join us. I need hardly say how welcome their presence is, nor how gladly we look forward to their taking part in our discussions, and aiding us by interchange of thought. To such a meeting the term 'international' seems almost misapplied. It may rather be described as a family gathering, in which our relatives more or less distant in blood, but still intimately connected with us by language, literature, and habits of thought, have spontaneously arranged to take part.

The domain of science is no doubt one in which the various nations of the civilised world meet upon equal terms, and for which no other passport is required than some evidence of having striven towards the advancement of natural knowledge. Here, on the frontier between the two great English-speaking nations of the world, who is there that does not inwardly feel that anything which conduces to an intimacy between the representatives of two countries, both of them actively engaged in the pursuit of science, may also, through such an intimacy, react on the affairs of daily life, and aid in preserving those cordial relations that have now for so many years existed between the great American Republic and the British Islands, with which her early foundations are indissolubly connected? The present year has witnessed an interchange of courtesies which has excited the warmest feelings of approbation on both sides of the Atlantic. I mean the return to its proper custodians of one of the most interesting of the relics of the Pilgrim Fathers, the Log of the 'Mayflower.' May this return, trifling in itself, be of happy augury as testifying to the feelings of mutual regard and esteem which animate the hearts both of the donors and of the recipients!

At our meeting in Montreal the President was an investigator who had already attained to a foremost place in the domains of Physics and

Mathematics, Lord Rayleigh. In his address he dealt mainly with topics, such as Light, Heat, Sound, and Electricity, on which he is one of our principal authorities. His name and that of his fellow-worker, Professor Ramsay, are now and will in all future ages be associated with the discovery of the new element, Argon. Of the ingenious methods by which that discovery was made, and the existence of Argon established, this is not the place to speak. One can only hope that the element will not always continue to justify its name by its inertness.

The claims of such a leader in physical science as Lord Rayleigh to occupy the Presidential chair are self-evident, but possibly those of his successor on this side of the Atlantic are not so immediately apparent. I cannot for a moment pretend to place myself on the same purely scientific level as my distinguished friend and for many years colleague, Lord Rayleigh, and my claims, such as they are, seem to me to rest on entirely different grounds.

Whatever little I may have indirectly been able to do in assisting to promote the advancement of science, my principal efforts have now for many years been directed towards attempting to forge those links in the history of the world, and especially of humanity, that connect the past with the present, and towards tracing that course of evolution which plays as important a part in the physical and moral development of man as it does in that of the animal and vegetable creation.

It appears to me, therefore, that my election to this important post may, in the main, be regarded as a recognition by this Association of the value of Archæology as a science.

Leaving all personal considerations out of question, I gladly hail this recognition, which is, indeed, in full accordance with the attitude already for many years adopted by the Association towards Anthropology, one of the most important branches of true Archæology.

It is no doubt hard to define the exact limits which are to be assigned to Archæology as a science, and Archæology as a branch of History and Belles Lettres. A distinction is frequently drawn between science on the one hand, and knowledge or learning on the other; but translate the terms into Latin, and the distinction at once disappears. In illustration of this I need only cite Bacon's great work on the 'Advancement of Learning,' which was, with his own aid, translated into Latin under the title '*De Augmentis Scientiarum.*'

It must, however, be acknowledged that a distinction does exist between Archæology proper, and what, for want of a better word, may be termed Antiquarianism. It may be interesting to know the internal arrangements of a Dominican convent in the middle ages; to distinguish between the different mouldings characteristic of the principal styles of Gothic architecture; to determine whether an English coin bearing the name of Henry was struck under Henry II., Richard, John, or Henry III., or to decide whether some given edifice was erected in Roman,

Saxon, or Norman times. But the power to do this, though involving no small degree of detailed knowledge and some acquaintance with scientific methods, can hardly entitle its possessors to be enrolled among the votaries of science.

A familiarity with all the details of Greek and Roman mythology and culture must be regarded as a literary rather than a scientific qualification; and yet when among the records of classical times we come upon traces of manners and customs which have survived for generations, and which seem to throw some rays of light upon the dim past, when history and writing were unknown, we are, I think, approaching the boundaries of scientific Archæology.

Every reader of Virgil knows that the Greeks were not merely orators, but that with a pair of compasses they could describe the movements of the heavens and fix the rising of the stars; but when by modern Astronomy we can determine the heliacal rising of some well-known star, with which the worship in some given ancient temple is known to have been connected, and can fix its position on the horizon at some particular spot, say, three thousand years ago, and then find that the axis of the temple is directed exactly towards that spot, we have some trustworthy scientific evidence that the temple in question must have been erected at a date approximately 1100 years B.C. If on or close to the same site we find that more than one temple was erected, each having a different orientation, these variations, following as they may fairly be presumed to do the changing position of the rising of the dominant star, will also afford a guide as to the chronological order of the different foundations. The researches of Mr. Penrose seem to show that in certain Greek temples, of which the date of foundation is known from history, the actual orientation corresponds with that theoretically deduced from astronomical data.

Sir J. Norman Lockyer has shown that what holds good for Greek temples applies to many of far earlier date in Egypt, though up to the present time hardly a sufficient number of accurate observations have been made to justify us in foreseeing all the instructive results that may be expected to arise from Astronomy coming to the aid of Archæology.

The intimate connection of Archæology with other sciences is in no case so evident as with respect to Geology, for when considering subjects such as those I shall presently discuss, it is almost impossible to say where the one science ends and the other begins.

By the application of geological methods many archæological questions relating even to subjects on the borders of the historical period have been satisfactorily solved. A careful examination of the limits of the area over which its smaller coins are found has led to the position of many an ancient Greek city being accurately ascertained; while in England it has only been by treating the coins of the Ancient Britons, belonging to a period before the Roman occupation, as if they were actual fossils, that the territories under the dominion of the various kings and princes who struck them have been approximately determined. In arranging the

chronological sequence of these coins, the evolution of their types—a process almost as remarkable, and certainly as well-defined, as any to be found in nature—has served as an efficient guide. I may venture to add that the results obtained from the study of the morphology of this series of coins were published ten years before the appearance of Darwin's great work on the 'Origin of Species.'

When we come to the consideration of the relics of the Early Iron and Bronze Ages, the aid of Chemistry has of necessity to be invoked. By its means we are able to determine whether the iron of a tool or weapon is of meteoritic or volcanic origin, or has been reduced from iron-ore, in which case considerable knowledge of metallurgy would be involved on the part of those who made it. With bronze antiquities the nature and extent of the alloys combined with the copper may throw light not only on their chronological position, but on the sources whence the copper, tin, and other metals of which they consist were originally derived. I am not aware of there being sufficient differences in the analyses of the native copper from different localities in the region in which we are assembled, for Canadian Archæologists to fix the sources from which the metal was obtained which was used in the manufacture of the ancient tools and weapons of copper that are occasionally discovered in this part of the globe.

Like Chemistry, Mineralogy and Petrology may be called to the assistance of Archæology in determining the nature and source of the rocks of which ancient stone implements are made; and, thanks to researches of the followers of those sciences, the old view that all such implements formed of jade and found in Europe must of necessity have been fashioned from material imported from Asia can no longer be maintained. In one respect the Archæologist differs in opinion from the Mineralogist—namely, as to the propriety of chipping off fragments from perfect and highly finished specimens for the purpose of submitting them to microscopic examination.

I have hitherto been speaking of the aid that other sciences can afford to Archæology when dealing with questions that come almost, if not quite, within the fringe of history, and belong to times when the surface of our earth presented much the same configuration as regards the distribution of land and water, and hill and valley, as it does at present, and when, in all probability, the climate was much the same as it now is. When, however, we come to discuss that remote age in which we find the earliest traces that are at present known of Man's appearance upon earth, the aid of Geology and Palæontology becomes absolutely imperative.

The changes in the surface configuration and in the extent of the land, especially in a country like Britain, as well as the modifications of the fauna and flora since those days, have been such that the Archæologist pure and simple is incompetent to deal with them, and he must either himself undertake the study of these other sciences or call experts in them

to his assistance. The evidence that Man had already appeared upon the earth is afforded by stone implements wrought by his hands, and it falls strictly within the province of the Archæologist to judge whether given specimens were so wrought or not ; it rests with the Geologist to determine their stratigraphical or chronological position, while the Palæontologist can pronounce upon the age and character of the associated fauna and flora.

If left to himself the Archæologist seems too prone to build up theories founded upon form alone, irrespective of geological conditions. The Geologist, unaccustomed to archæological details, may readily fail to see the difference between the results of the operations of Nature and those of Art, and may be liable to trace the effects of man's handiwork in the chipping, bruising, and wearing which in all ages result from natural forces ; but the united labours of the two, checked by those of the Palæontologist, cannot do otherwise than lead towards sound conclusions.

It will perhaps be expected of me that I should on the present occasion bring under review the state of our present knowledge with regard to the Antiquity of Man ; and probably no fitter place could be found for the discussion of such a topic than the adopted home of my venerated friend, the late Sir Daniel Wilson, who first introduced the word 'prehistoric' into the English language.

Some among us may be able to call to mind the excitement, not only among men of science but among the general public, when, in 1859, the discoveries of M. Boucher de Perthes and Dr. Rigollot in the gravels of the valley of the Somme, at Abbeville and Amiens, were confirmed by the investigations of the late Sir Joseph Prestwich, myself, and others, and the co-existence of Man with the extinct animals of the Quaternary fauna, such as the mammoth and woolly-haired rhinoceros, was first virtually established. It was at the same time pointed out that these relics belonged to a far earlier date than the ordinary stone weapons found upon the surface, which usually showed signs of grinding or polishing, and that in fact there were two Stone Ages in Britain. To these the terms Neolithic and Palæolithic were subsequently applied by Sir John Lubbock.

The excitement was not less, when, at the meeting of this Association at Aberdeen in the autumn of that year, Sir Charles Lyell, in the presence of the Prince Consort, called attention to the discoveries in the valley of the Somme, the site of which he had himself visited, and to the vast lapse of time indicated by the position of the implements in drift-deposits a hundred feet above the existing river.

The conclusions forced upon those who examined the facts on the spot did not receive immediate acceptance by all who were interested in Geology and Archæology, and fierce were the controversies on the subject that were carried on both in the newspapers and before various learned societies.

It is at the same time instructive and amusing to look back on the discussions of those days. While one class of objectors accounted for the configuration of the flint implements from the gravels by some unknown chemical agency, by the violent and continued gyratory action of water, by fracture resulting from pressure, by rapid cooling when hot or by rapid heating when cold, or even regarded them as aberrant forms of fossil fishes, there were others who, when compelled to acknowledge that the implements were the work of men's hands, attempted to impugn and set aside the evidence as to the circumstances under which they had been discovered. In doing this they adopted the view that the worked flints had either been introduced into the containing beds at a comparatively recent date, or if they actually formed constituent parts of the gravel then that this was a mere modern alluvium resulting from floods at no very remote period.

In the course of a few years the main stream of scientific thought left this controversy behind, though a tendency to cut down the lapse of time necessary for all the changes that have taken place in the configuration of the surface of the earth and in the character of its occupants since the time of the Palæolithic gravels, still survives in the inmost recesses of the hearts of not a few observers.

In his Address to this Association at the Bath meeting of 1864, Sir Charles Lyell struck so true a note that I am tempted to reproduce the paragraph to which I refer :—

'When speculations on the long series of events which occurred in the glacial and post-glacial periods are indulged in, the imagination is apt to take alarm at the immensity of the time required to interpret the monuments of these ages, all referable to the era of existing species. In order to abridge the number of centuries which would otherwise be indispensable, a disposition is shown by many to magnify the rate of change in prehistoric times by investing the causes which have modified the animate and inanimate world with extraordinary and excessive energy. It is related of a great Irish orator of our day that when he was about to contribute somewhat parsimoniously towards a public charity, he was persuaded by a friend to make a more liberal donation. In doing so he apologized for his first apparent want of generosity by saying that his early life had been a constant struggle with scanty means, and that "they who are born to affluence cannot easily imagine how long a time it takes to get the chill of poverty out of one's bones." In like manner we of the living generation, when called upon to make grants of thousands of centuries in order to explain the events of what is called the modern period, shrink naturally at first from making what seems so lavish an expenditure of past time. Throughout our early education we have been accustomed to such strict economy in all that relates to the chronology of the earth and its inhabitants in remote ages, so fettered have we been by old traditional beliefs, that even when our reason is convinced, and we

are persuaded that we ought to make more liberal grants of time to the Geologist, we feel how hard it is to get the chill of poverty out of our bones.'

Many, however, have at the present day got over this feeling, and of late years the general tendency of those engaged upon the question of the antiquity of the human race has been in the direction of seeking for evidence by which the existence of Man upon the earth could be carried back to a date earlier than that of the Quaternary gravels.

There is little doubt that such evidence will eventually be forthcoming, but, judging from all probability, it is not in Northern Europe that the cradle of the human race will eventually be discovered, but in some part of the world more favoured by a tropical climate, where abundant means of subsistence could be procured, and where the necessity for warm clothing did not exist.

Before entering into speculations on this subject, or attempting to lay down the limits within which we may safely accept recent discoveries as firmly established, it will be well to glance at some of the cases in which implements are stated to have been found under circumstances which raise a presumption of the existence of man in pre-Glacial, Pliocene, or even Miocene times.

Flint implements of ordinary Palæolithic type have, for instance, been recorded as found in the Eastern Counties of England, in beds beneath the Chalky Boulder Clay; but on careful examination the geological evidence has not to my mind proved satisfactory, nor has it, I believe, been generally accepted. Moreover, the archæological difficulty that Man, at two such remote epochs as the pre-Glacial and the post-Glacial, even if the term Glacial be limited to the Chalky Boulder Clay, should have manufactured implements so identical in character that they cannot be distinguished apart, seems to have been entirely ignored.

Within the last few months we have had the report of worked flints having been discovered in the late Pliocene Forest Bed of Norfolk, but in that instance the signs of human workmanship upon the flints are by no means apparent to all observers.

But such an antiquity as that of the Forest Bed is as nothing when compared with that which would be implied by the discoveries of the work of men's hands in the Pliocene and Miocene beds of England, France, Italy, and Portugal, which have been accepted by some Geologists. There is one feature in these cases which has hardly received due attention, and that is the isolated character of the reputed discoveries. Had man, for instance, been present in Britain during the Crag Period, it would be strange indeed if the sole traces of his existence that he left were a perforated tooth of a large shark, the sawn rib of a manatee, and a beaming full face, carved on the shell of a pectunculus!

In an address to the Anthropological Section at the Leeds meeting of this Association in 1890 I dealt somewhat fully with these supposed

discoveries of the remains of human art in beds of Tertiary date; and I need not here go further into the question. Suffice it to say that I see no reason why the verdict of 'not proven' at which I then arrived should be reversed.

In the case of a more recent discovery in Upper Burma in beds at first pronounced to be Upper Miocene, but subsequently 'definitely ascertained to be Pliocene,' some of the flints are of purely natural and not artificial origin, so that two questions arise: first, Were the fossil remains associated with the worked flints or with those of natural forms? And second, Were they actually found in the bed to which they have been assigned, or did they merely lie together on the surface?

Even the *Pithecanthropus erectus* of Dr. Eugène Dubois from Java meets with some incredulous objectors from both the physiological and the geological sides. From the point of view of the latter the difficulty lies in determining the exact age of what are apparently alluvial beds in the bottom of a river valley.

When we return to Palæolithic man, it is satisfactory to feel that we are treading on comparatively secure ground, and that the discoveries of the last forty years in Britain alone enable us to a great extent to reconstitute his history. We may not know the exact geological period when first he settled in the British area, but we have good evidence that he occupied it at a time when the configuration of the surface was entirely different from what it is at present: when the river valleys had not been cut down to anything like their existing depth, when the fauna of the country was of a totally different character from that of the present day, when the extension of the southern part of the island seaward was in places such that the land was continuous with that of the continent, and when in all probability a far more rainy climate prevailed. We have proofs of the occupation of the country by man during the long lapse of time that was necessary for the excavation of the river valleys. We have found the old floors on which his habitations were fixed, we have been able to trace him at work on the manufacture of flint instruments, and by building up the one upon the other the flakes struck off by the primæval workman in those remote times we have been able to reconstruct the blocks of flint which served as his material.

That the duration of the Palæolithic Period must have extended over an almost incredible length of time is sufficiently proved by the fact that valleys, some miles in width and of a depth of from 100 to 150 feet, have been eroded since the deposit of the earliest implement-bearing beds. Nor is the apparent duration of this period diminished by the consideration that the floods which hollowed out the valleys were not in all probability of such frequent occurrence as to teach Palæolithic man by experience the danger of settling too near to the streams, for had he kept to the higher slopes of the valley there would have been but little chance of his implements having so constantly formed constituent parts of the gravels deposited by the floods.

The examination of British cave-deposits affords corroborative evidence of this extended duration of the Palæolithic Period. In Kent's Cavern at Torquay, for instance, we find in the lowest deposit, the breccia below the red cave-earth, implements of flint and chert corresponding in all respects with those of the high level and most ancient river gravels. In the cave-earth these are scarcer, though implements occur which also have their analogues in the river deposits; but, what is more remarkable, harpoons of reindeer's horn and needles of bone are present, identical in form and character with those of the caverns of the Reindeer Period in the South of France, and suggestive of some bond of union or identity of descent between the early troglodytes, whose habitations were geographically so widely separated the one from the other.

In a cavern at Creswell Crags, on the confines of Derbyshire and Nottinghamshire, a bone has moreover been found engraved with a representation of parts of a horse in precisely the same style as the engraved bones of the French caves.

It is uncertain whether any of the River-drift specimens belong to so late a date as these artistic cavern-remains; but the greatly superior antiquity of even these to any Neolithic relics is testified by the thick layer of stalagmite, which had been deposited in Kent's Cavern before its occupation by men of the Neolithic and Bronze Periods.

Towards the close of the period covered by the human occupation of the French caves, there seems to have been a dwindling in the number of the larger animals constituting the Quaternary fauna, whereas their remains are present in abundance in the lower and therefore more recent of the valley gravels. This circumstance may afford an argument in favour of regarding the period represented by the later French caves as a continuation of that during which the old river gravels were deposited, and yet the great change in the fauna that has taken place since the latest of the cave-deposits included in the Palæolithic Period is indicative of an immense lapse of time.

How much greater must have been the time required for the more conspicuous change between the old Quaternary fauna of the river gravels and that characteristic of the Neolithic Period!

As has been pointed out by Prof. Boyd Dawkins, only thirty-one out of the forty-eight well-ascertained species living in the post-Glacial or River-drift Period survived into pre-historic or Neolithic times. We have not, indeed, any means at command for estimating the number of centuries which such an important change indicates; but when we remember that the date of the commencement of the Neolithic or Surface Stone Period is still shrouded in the mist of a dim antiquity, and that prior to that commencement the River-drift Period had long come to an end; and when we further take into account the almost inconceivable ages that even under the most favourable conditions the excavation of wide and deep valleys by river action implies, the remoteness of the date

at which the Palæolithic Period had its beginning almost transcends our powers of imagination.

We find distinct traces of river action from 100 to 200 feet above the level of existing streams and rivers, and sometimes at a great distance from them; we observe old fresh-water deposits on the slopes of valleys several miles in width; we find that long and lofty escarpments of rock have receded unknown distances since their summits were first occupied by Palæolithic man; we see that the whole side of a wide river valley has been carried away by an invasion of the sea, which attacked and removed a barrier of chalk cliffs from 400 to 600 feet in height; we find that what was formerly an inland river has been widened out into an arm of the sea, now the highway of our fleets, and that gravels which were originally deposited in the bed of some ancient river now cap isolated and lofty hills.

And yet, remote as the date of the first known occupation of Britain by man may be, it belongs to what, geologically speaking, must be regarded as a quite recent period, for we are now in a position to fix with some degree of accuracy its place on the geological scale. Thanks to investigations ably carried out at Hoxne in Suffolk, and at Hitchin in Hertfordshire, by Mr. Clement Reid, under the auspices of this Association and of the Royal Society, we know that the implement-bearing beds at those places undoubtedly belong to a time subsequent to the deposit of the Great Chalky Boulder Clay of the Eastern Counties of England. It is, of course, self-evident that this vast deposit, in whatever manner it may have been formed, could not, for centuries after its deposition was complete, have presented a surface inhabitable by man. Moreover, at a distance but little farther north, beds exist which also, though at a somewhat later date, were apparently formed under Glacial conditions. At Hoxne the interval between the deposit of the Boulder Clay and of the implement-bearing beds is distinctly proved to have witnessed at least two noteworthy changes in climate. The beds immediately reposing on the Clay are characterised by the presence of alder in abundance, of hazel, and yew, as well as by that of numerous flowering plants indicative of a temperate climate very different from that under which the Boulder Clay itself was formed. Above these beds characterised by temperate plants, comes a thick and more recent series of strata, in which leaves of the dwarf Arctic willow and birch abound, and which were in all probability deposited under conditions like those of the cold regions of Siberia and North America.

At a higher level and of more recent date than these—from which they are entirely distinct—are the beds containing Palæolithic implements, formed in all probability under conditions not essentially different from those of the present day. However this may be, we have now conclusive evidence that the Palæolithic implements are, in the Eastern Counties of England, of a date long posterior to that of the Great Chalky Boulder Clay.

It may be said, and said truly, that the implements at Hoxne cannot be shown to belong to the beginning rather than to some later stage of the Palæolithic Period. The changes, however, that have taken place at Hoxne in the surface configuration of the country prove that the beds containing the implements cannot belong to the close of that period.

It must, moreover, be remembered that in what are probably the earliest of the Palæolithic deposits of the Eastern Counties, those at the highest level, near Brandon in Norfolk, where the gravels contain the largest proportion of pebbles derived from Glacial beds, some of the implements themselves have been manufactured from materials not native to the spot but brought from a distance, and derived in all probability either from the Boulder Clay or from some of the beds associated with it.

We must, however, take a wider view of the whole question, for it must not for a moment be supposed that there are the slightest grounds for believing that the civilisation, such as it was, of the Palæolithic Period originated in the British Isles. We find in other countries implements so identical in form and character with British specimens that they might have been manufactured by the same hands. These occur over large areas in France under similar conditions to those that prevail in England. The same forms have been discovered in the ancient river gravels of Italy, Spain, and Portugal. Some few have been recorded from the north of Africa, and analogous types occur in considerable numbers in the south of that continent. On the banks of the Nile, many hundreds of feet above its present level, implements of the European types have been discovered; while in Somaliland, in an ancient river valley at a great elevation above the sea, Mr. Seton-Karr has collected a large number of implements formed of flint and quartzite, which, judging from their form and character, might have been dug out of the drift deposits of the Somme or the Seine, the Thames or the ancient Solent.

In the valley of the Euphrates implements of the same kind have also been found, and again farther east in the lateritic deposits of Southern India they have been obtained in considerable numbers. It is not a little remarkable, and is at the same time highly suggestive, that a form of implement almost peculiar to Madras reappears among implements from the very ancient gravels of the Manzanares at Madrid. In the case of the African discoveries we have as yet no definite Palæontological evidence by which to fix their antiquity, but in the Narbadá Valley of Western India Palæolithic implements of quartzite seem to be associated with a local fauna of Pleistocene age, comprising, like that of Europe, the elephant, hippopotamus, ox, and other mammals of species now extinct. A correlation of the two faunas with a view of ascertaining their chronological relations is beset with many difficulties, but there seems reason for accepting this Indian Pleistocene fauna as in some degree more ancient than the European.

Is this not a case in which the imagination may be fairly invoked in aid of science? May we not from these data attempt in some degree to build up and reconstruct the early history of the human family? There, in Eastern Asia, in a tropical climate, with the means of subsistence readily at hand, may we not picture to ourselves our earliest ancestors gradually developing from a lowly origin, acquiring a taste for hunting, if not indeed being driven to protect themselves from the beasts around them, and evolving the more complicated forms of tools or weapons from the simpler flakes which had previously served them as knives? May we not imagine that, when once the stage of civilisation denoted by these Palæolithic implements had been reached, the game for the hunter became scarcer, and that his life in consequence assumed a more nomad character? Then, and possibly not till then, may a series of migrations to 'fresh woods and pastures new' not unnaturally have ensued, and these following the usual course of 'westward towards the setting sun' might eventually lead to a Palæolithic population finding its way to the extreme borders of Western Europe, where we find such numerous traces of its presence.

How long a term of years may be involved in such a migration it is impossible to say, but that such a migration took place the phenomena seem to justify us in believing. It can hardly be supposed that the process that I have shadowed forth was reversed, and that Man, having originated in North-Western Europe, in a cold climate where clothing was necessary and food scarce, subsequently migrated eastward to India and southward to the Cape of Good Hope! As yet, our records of discoveries in India and Eastern Asia are but scanty; but it is there that the traces of the cradle of the human race are, in my opinion, to be sought, and possibly future discoveries may place upon a more solid foundation the visionary structure that I have ventured to erect.

It may be thought that my hypothesis does not do justice to what Sir Thomas Browne has so happily termed 'that great antiquity, America.' I am, however, not here immediately concerned with the important Neolithic remains of all kinds with which this great continent abounds. I am now confining myself to the question of Palæolithic man and his origin, and in considering it I am not unmindful of the Trenton implements, though I must content myself by saying that the 'turtle-back' form is essentially different from the majority of those on the wide dissemination of which I have been speculating, and, moreover, as many here present are aware, the circumstances of the finding of these American implements are still under careful discussion.

Leaving them out of the question for the present, it may be thought worth while to carry our speculations rather further, and to consider the relations in time between the Palæolithic and the Neolithic Periods. We have seen that the stage in human civilisation denoted by the use of the ordinary forms of Palæolithic implements must have extended over a vast

period of time if we have to allow for the migration of the primæval hunters from their original home, wherever it may have been in Asia or Africa, to the west of Europe, including Britain. We have seen that, during this migration, the forms of the weapons and tools made from silicious stones had become, as it were, stereotyped, and further, that, during the subsequent extended period implied by the erosion of the valleys, the modifications in the form of the implements and the changes in the fauna associated with the men who used them were but slight.

At the close of the period during which the valleys were being eroded comes that represented by the latest occupation of the caves by Palæolithic man, when both in Britain and in the south of France the reindeer was abundant; but among the stone weapons and implements of that long troglodytic phase of man's history not a single example with the edge sharpened by grinding has as yet been found. All that can safely be said is that the larger implements as well as the larger mammals had become scarcer, that greater power in chipping flint had been attained, that the arts of the engraver and the sculptor had considerably developed, and that the use of the bow had probably been discovered.

Directly we encounter the relics of the Neolithic Period, often, in the case of the caves lately mentioned, separated from the earlier remains by a thick layer of underlying stalagmite, we find flint hatchets polished at the edge and on the surface, cutting at the broad and not at the narrow end, and other forms of implements associated with a fauna in all essential respects identical with that of the present day.

Were the makers of these polished weapons the direct descendants of Palæolithic ancestors whose occupation of the country was continuous from the days of the old river gravels? or had these long since died out, so that after Western Europe had for ages remained uninhabited, it was re-peopled in Neolithic times by the immigration of some new race of men? Was there, in fact, a 'great gulf fixed' between the two occupations? or was there in Europe a gradual transition from the one stage of culture to the other?

It has been said that 'what song the Syrens sang, or what name Achilles assumed when he hid himself among women, though puzzling questions, are not beyond all conjecture'; and though the questions now proposed may come under the same category, and must await the discovery of many more essential facts before they receive definite and satisfactory answers, we may, I think, throw some light upon them if we venture to take a few steps upon the seductive if insecure paths of conjecture. So far as I know we have as yet no trustworthy evidence of any transition from the one age to the other, and the gulf between them remains practically unbridged. We can, indeed, hardly name the part of the world in which to seek for the cradle of Neolithic civilisation, though we know that traces of what appear to have been a stone-using people have been discovered in Egypt, and that what must be among the latest

of the relics of their industry have been assigned to a date some 3,500 to 4,000 years before our era. The men of that time had attained to the highest degree of skill in working flint that has ever been reached. Their beautifully made knives and spear-heads seem indicative of a culminating point reached after long ages of experience; but whence these artists in flint came or who they were is at present absolutely unknown, and their handiworks afford no clue to help us in tracing their origin.

Taking a wider survey, we may say that, generally speaking, not only the fauna but the surface configuration of the country were, in Western Europe at all events, much the same at the commencement of the Neolithic Period as they are at the present day. We have, too, no geological indications to aid us in forming any chronological scale.

The occupation of some of the caves in the south of France seems to have been carried on after the erosion of the neighbouring river valleys had ceased, and so far as our knowledge goes these caves offer evidence of being the latest in time of those occupied by Man during the Palæolithic Period. It seems barely possible that, though in the north of Europe there are no distinct signs of such late occupation, yet that, in the south, Man may have lived on, though in diminished numbers; and that in some of the caves, such, for instance, as those in the neighbourhood of Mentone, there may be traces of his existence during the transitional period that connects the Palæolithic and Neolithic Ages. If this were really the case, we might expect to find some traces of a dissemination of Neolithic culture from a North Italian centre, but I much doubt whether any such traces actually exist.

If it had been in that part of the world that the transition took place, how are we to account for the abundance of polished stone hatchets found in Central India? Did Neolithic man return eastward by the same route as that by which in remote ages his Palæolithic predecessor had migrated westward? Would it not be in defiance of all probability to answer such a question in the affirmative? We have, it must be confessed, nothing of a substantial character to guide us in these speculations; but, pending the advent of evidence to the contrary, we may, I think, provisionally adopt the view that owing to failure of food, climatal changes, or other causes, the occupation of Western Europe by Palæolithic man absolutely ceased, and that it was not until after an interval of long duration that Europe was re-peopled by a race of men immigrating from some other part of the globe where the human race had survived, and in course of ages had developed a higher stage of culture than that of Palæolithic man.

I have been carried away by the liberty allowed for conjecture into the regions of pure imagination, and must now return to the realms of fact, and one fact on which I desire for a short time to insist is that of the existence at the present day, in close juxtaposition with our own civilisation, of races of men who, at all events but a few generations ago,

lived under much the same conditions as did our own Neolithic predecessors in Europe.

The manners and customs of these primitive tribes and peoples are changing day by day, their languages are becoming obsolete, their myths and traditions are dying out, their ancient processes of manufacture are falling into oblivion, and their numbers are rapidly diminishing, so that it seems inevitable that ere long many of these interesting populations will become absolutely extinct. The admirable Bureau of Ethnology instituted by our neighbours in the United States of America has done much towards preserving a knowledge of the various native races in this vast continent; and here in Canada the annual Archæological Reports presented to the Minister of Education are rendering good service in the same cause.

Moreover the Committee of this Association appointed to investigate the physical characters, languages, and industrial and social conditions of the North-Western tribes of the Dominion of Canada is about to present its twelfth and final report, which in conjunction with those already presented will do much towards preserving a knowledge of the habits and languages of those tribes. It is sad to think that Mr. Horatio Hale, whose comprehensive grasp of the bearings of ethnological questions, and whose unremitting labours have so materially conduced to the success of the Committee, should be no longer among us. Although this report is said to be final, it is to be hoped that the Committee may be able to indicate lines upon which future work in the direction of ethnological and archæological research may be profitably carried on in this part of Her Majesty's dominions.

It is, however, lamentable to notice how little is being or has been officially done towards preserving a full record of the habits, beliefs, arts, myths, languages, and physical characteristics of the countless other tribes and nations more or less uncivilised which are comprised within the limits of the British Empire. At the meeting of this Association held last year at Liverpool it was resolved by the General Committee 'that it is of urgent importance to press upon the Government the necessity of establishing a Bureau of Ethnology for Greater Britain, which by collecting information with regard to the native races within and on the borders of the Empire will prove of immense value to science and to the Government itself.' It has been suggested that such a bureau might with the greatest advantage and with the least outlay and permanent expense be connected either with the British Museum or with the Imperial Institute, and the project has already been submitted for the consideration of the Trustees of the former establishment.

The existence of an almost unrivalled ethnological collection in the Museum, and the presence there of officers already well versed in ethnological research, seem to afford an argument in favour of the proposed bureau being connected with it. On the other hand, the Imperial Insti-

tute was founded with an especial view to its being a centre around which every interest connected with the dependencies of the Empire might gather for information and support. The establishment within the last twelve months of a Scientific Department within the Institute, with well-appointed laboratories and a highly trained staff, shows how ready are those concerned in its management to undertake any duties that may conduce to the welfare of the outlying parts of the British Empire; a fact of which I believe that Canada is fully aware. The Institute is therefore likely to develop, so far as its scientific department is concerned, into a Bureau of advice in all matters scientific and technical, and certainly a Bureau of Ethnology such as that suggested would not be out of place within its walls.

Wherever such an institution is to be established, the question of its existence must of necessity rest with Her Majesty's Government and Treasury, inasmuch as without funds, however moderate, the undertaking cannot be carried on. I trust that in considering the question it will always be borne in mind that in the relations between civilised and uncivilised nations and races it is of the first importance that the prejudices and especially the religious or semi-religious and caste prejudices of the latter should be thoroughly well known to the former. If but a single 'little war' could be avoided in consequence of the knowledge acquired and stored up by the Bureau of Ethnology preventing such a misunderstanding as might culminate in warfare, the cost of such an institution would quickly be saved.

I fear that it will be thought that I have dwelt too long on primæval man and his modern representatives, and that I should have taken this opportunity to discuss some more general subject, such as the advances made in the various departments of science since last this Association met in Canada. Such a subject would no doubt have afforded an infinity of interesting topics on which to dilate. Spectrum analysis, the origin and nature of celestial bodies, photography, the connection between heat, light, and electricity, the practical applications of the latter, terrestrial magnetism, the liquefaction and solidification of gases, the behaviour of elements and compounds under the influence of extreme cold, the nature and uses of the Röntgen rays, the advances in bacteriology and in prophylactic medicine, might all have been passed under review, and to many of my audience would have seemed to possess greater claims to attention than the subject that I have chosen.

It must, however, be borne in mind that most, if not indeed all, of these topics will be discussed by more competent authorities in the various Sections of the Association by means of the Presidential addresses or otherwise. Nor must it be forgotten that I occupy this position as a representative of Archæology, and am therefore justified in bringing before you a subject in which every member of every race of mankind ought to be interested—the antiquity of the human family and the scenes of its infancy.

Others will direct our thoughts in other directions, but the farther we proceed the more clearly shall we realise the connection and interdependence of all departments of science. Year after year, as meetings of this Association take place, we may also foresee that 'many shall run to and fro and knowledge shall be increased.' Year after year advances will be made in science, and in reading that Book of Nature that lies ever open before our eyes; successive stones will be brought for building up that Temple of Knowledge of which our fathers and we have laboured to lay the foundations. May we not well exclaim with old Robert Recorde?—

'Oh woorthy temple of Goddes magnificence: Oh throne of glorye and seate of the lorde: thy substance most pure what tonge can describe? thy signes are so wonderous, surmountinge mannes witte, the effects of thy motions so diuers in kinde: so harde for to searche, and worse for to fynde—Thy woorkes are all wonderous, thy cunning unknowen: yet seedes of all knowledge in that booke are sowen—And yet in that boke who rightly can reade, to all secrete knowledge it will him straighte reade'[1]

[1] Preface to Robert Recorde's *Castle of Knowledge*, 1556.

REPORTS

ON THE

STATE OF SCIENCE.

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Corresponding Societies Committee.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Sir DOUGLAS GALTON, Sir RAWSON RAWSON, Mr. G. J. SYMONS, Dr. J. G. GARSON, Sir JOHN EVANS, Mr. J. HOPKINSON, Professor T. G. BONNEY, Mr. W. WHITAKER, Professor E. B. POULTON, Mr. CUTHBERT PEEK, *and* Rev. Canon H. B. TRISTRAM.

THE following Corresponding Societies nominated delegates to the Toronto meeting. The attendance of the delegate at the first meeting of the Conference is indicated by the letter A, and at the second by the letter B.

A	Andersonian Naturalists' Society	Malcolm Laurie, B.Sc.
	Belfast Natural History and Philosophical Society	William Swanston, F.G.S.
	Belfast Naturalists' Field Club	
A B	Berwickshire Naturalists' Field Club	G. P. Hughes.
	Buchan Field Club	John Gray, B.Sc.
A B	Caradoc and Severn Valley Field Club	John Hopkinson, F.L.S., F.G.S.
	Cardiff Naturalists' Society	Professor J. Viriamu Jones, F.R.S.
B	Dublin Naturalists' Field Club	Professor A. C. Haddon, B.Sc.
	East Kent Natural History Society	A. S. Reid, M.A., F.G.S.
A B	East of Scotland Union of Naturalists' Societies	H. R. Mill, D.Sc.
A B	Essex Field Club	Professor R. Meldola, F.R.S.
B	Federated Institution of Mining Engineers	Archibald Blue.
B	Glasgow Natural History Society	Professor E. E. Prince, B.A.
A B	Hertfordshire Natural History Society	John Hopkinson, F.L.S., F.G.S.
A B	Isle of Man Natural History and Antiquarian Society	G. W. Lamplugh, F.G.S.
	Leeds Naturalists' Club	Harold Wager, F.L.S.
A	Liverpool Geological Society	Professor W. A. Herdman, F.R.S.
A B	Manchester Geographical Society	W. E. Hoyle, M.A.
A B	Manchester Microscopical Society	Professor F. E. Weiss, B.Sc., F.L.S.
	North of England Institute of Mining and Mechanical Engineers	W. Hamilton Merritt.
A B	North Staffordshire Naturalists' Field Club	W. D. Spanton, F.R.C.S.
A B	Perthshire Society of Natural Science	H. R. Mill, D.Sc.

A	Woolhope Naturalists' Field Club . .	Rev. J. O. Bevan, M.A., F.G.S.
A B	Yorkshire Geological and Polytechnic Society	G. W. Lamplugh, F.G.S.
B	Yorkshire Naturalists' Union . . .	Professor L. C. Miall, F.R.S., F.L.S.

The first meeting of the Conference was held in the University of Toronto on Thursday, August 19. The Corresponding Societies Committee were represented by Professor Meldola, F.R.S., Chairman, and Mr. John Hopkinson, Secretary of the Conference.

The Chairman suggested that, in view of the smallness of the gathering (only eleven delegates being present), a paper on the Museums of Canada, by Dr. Henry M. Ami, of Ottawa, be deferred to the next meeting. At the Liverpool Conference the question of federation amongst the local Natural History Societies of Great Britain had been referred to the Corresponding Societies Committee, and the action of the Committee had been embodied in the Report, which the Secretary would now read.

Mr. Hopkinson then read the following Report of the Corresponding Societies Committee:—

The Corresponding Societies Committee of the British Association beg leave to submit to the General Committee the following Report of the results of an attempt made, since the Liverpool Meeting, to obtain the opinions of the local scientific Societies on the question of the desirability of a much greater amount of federation among them than at present prevails.

In accordance with the decision of the Committee at a meeting held October 29, 1896, copies of Mr. Abbott's scheme for the formation of District Unions of Natural History Societies (which was discussed at the Liverpool Conference of Delegates of the Corresponding Societies) were forwarded to the sixty-six Corresponding Societies and to fifty-eight others, together with the following letter:—

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
BURLINGTON HOUSE, LONDON, W.

November 1896.

SIR,—We are requested by the Corresponding Societies Committee to call your attention to a scheme drawn up by Mr. George Abbott (General Secretary of the South-Eastern Union of Scientific Societies) for promoting District Unions of Natural History Societies, a copy of which is inclosed. This scheme was discussed at the Conference of Delegates of the Corresponding Societies of the British Association held at the Liverpool Meeting of the Association last September, when the great advantages of federation were generally admitted, and some examples of it were explained. At a meeting of the Corresponding Societies Committee on October 29 the Report of the Conference of Delegates was considered, and it was decided that, as the circumstances in which the local Societies are placed are extremely varied, it is desirable that each Society shall be asked its opinion on Mr. Abbott's scheme, and as to what kind of federation it considers to be the best. We have therefore to state that the Corresponding Societies Committee will be greatly obliged if your Society will be good enough to favour them with its views on the subject at any date not later than December 20, 1896.

We are, Sir, yours faithfully,
R. MELDOLA, *Chairman*,
T. V. HOLMES, *Secretary*,
Corresponding Societies Committee, British Association.

The Secretary.

When the Committee met on March 19, 1897, only twenty-six answers had been received. The Secretary was accordingly directed to write to eleven of the Corresponding Societies which had not replied asking for some expression of their views on the subject of federation before the end of April. This second application produced eight additional replies, making the total received thirty-four, which may be thus classed :—

Answers from Corresponding Societies	20
„ „ other local Societies	14
	34

As regards the nature of the replies the Societies may be thus arranged :—

Belong to Unions already	9
In close touch with a Union	1
Prevented by circumstances from joining Unions	2
Undecided	4
Generally favourable to Unions	9
Unfavourable in their own cases	9
	34

The answers received from Societies which already belong to a Union, or are in close touch with one, call for no remark. The two Societies prevented by circumstances from joining Unions are the Cambridge Philosophical Society and the Marlborough College Natural History Society. In the replies from the four Societies classed as 'undecided,' perhaps the most significant remark is to the effect that the Club in question is doubtful whether economy of energy might not be dearly purchased by loss of enthusiasm, and whether 'a deadening uniformity' might not result from Unions. Of the nine Societies generally favourable to Unions, two only, the Hertfordshire Natural History Society and the Leicester Literary and Philosophical Society, sent definite, detailed plans of what they proposed to accomplish in their own localities. And a third, the Essex Field Club, stated that it was in communication with the Norfolk and Norwich Natural History Society with the view of establishing some degree of co-operation between the two Societies in the future. The others contented themselves with the remark that union was a step in the right direction, or with some other phrase expressing vague approval.

The replies received from the Societies classed as 'unfavourable in their own cases' vary very much as to their approval of federation in the abstract. All these Societies are Corresponding Societies, and have counties or other large areas as their spheres of work.

It is noticeable that while most of the replies received before March 19 were, more or less, favourable to federation, those sent in answer to the second application are all, more or less, unfavourable. This difference between the character of the earlier and the later replies seems to point to the conclusion that the local Societies addressed which have sent no

answer—90 out of 124—have abstained either because they are wholly uninterested in schemes of federation, or are more or less unfavourable to them. Judging from answers received, it would appear that Societies having a whole county or some district of similar size as their sphere of operations are usually indifferent, or averse, to union with adjacent counties or districts. Members of such Societies do not generally feel a strong local interest in larger areas, and at the same time they do not need the help of other Societies in the publication of their transactions. On the other hand, experience shows that a large number of the smaller local Societies are associations rather for lectures and excursions than for local scientific work. And the brief annual reports they issue are of little interest, except to their own members. Consequently they also are uninterested in questions about federation.

A feeling unfavourable to federation may result from the existence in a district of two large towns of nearly equal importance within a few miles of each other. Thus both the Bath Natural History and Antiquarian Field Club and the Bristol Naturalists' Society report that some years ago an unsuccessful attempt was made to promote some kind of union among the local Societies there.

A glance at the Federations of the past may be of use. Three or four years ago the Midland Naturalists' Union and the Cumberland and Westmorland Association both came to an end, after the former had existed sixteen years, and the latter a few months longer. The ultimate failure of the Midland Union was, in all probability, largely due to the want of any common feeling among its members of being 'Midlanders.' But Cumberland and Westmorland are two counties which have a strong affinity for each other, and have been much associated together in many ways. Possibly the ultimate failure of their Association may have been mainly the result of the absence of any town in those counties so pre-eminent in size and importance as to be able to form a recognised standard and central Society.

Two Societies, which once belonged to the Midland Union, express a preference for Unions like the Yorkshire Naturalists' Union. The great advantage possessed by that federation lies, however, in the fact that all its members, though they may live as far apart as any members of the Midland Union once did, have the common feeling of being Yorkshiremen. But Warwickshire, for example, may feel no special affinity for Nottinghamshire, or the county of Leicester for that of Stafford.

In short, while no one can doubt the great desirability on all grounds of increased federation among the various local Societies, it is obvious that success must depend, not on the abstract merits of any given scheme, but on its suitability to the local conditions in which it is expected to work.

Some disappointment may be felt at the slightness of the interest manifested in federation. But it may be hoped that many Societies which are more or less averse to any close federation with neighbouring Associations have, nevertheless, had their thoughts profitably directed towards

the attainment of a much greater amount of mutual co-operation and assistance than at present prevails.

The following Societies have been added to the list of the Corresponding Societies :—

1. The Halifax Scientific Society and Geologists' Field Club.
2. The Brighton and Sussex Natural History and Philosophical Society.
3. The Andersonian Naturalists' Society.

The Chairman, in inviting discussion, said that there were great differences of opinion with regard to federation, but he thought that much good might result from some such scheme as the grouping of counties for occasional meetings of their Local Societies, if for no other purpose than to avoid duplication of work. By the proceedings of Local Societies being collected into one publication, diffuseness would be avoided, and the money spent by individual Societies upon printing might profitably be diverted into other channels.

Professor Herdman said that many scientific men in provincial towns like Liverpool had thought a great deal about this question in recent years, but there were many difficulties in the way, some of which he discussed. As a matter of history, for one or other of these reasons, every attempt made by the Liverpool Geological and Biological Societies to decide upon a line of action with other Local Societies had ended in failure. Office-bearers in active Societies of good standing were, as a rule, opposed to federation, and if there were one subscription to federated Societies the income of each individual Society would be reduced.

Dr. H. R. Mill stated that the East of Scotland Union of Naturalists' Societies was very successful, all the members of the federated Societies having the same feeling of local patriotism, and that the Perthshire Society of Natural Science was one of the best of these Local Societies, its museum being one of the sights of Perth. The Kirkcaldy Natural History Society was also one of the best in the Union. These Societies meet in different towns each year, have joint excursions, and are so satisfactorily related as to give him great faith in the importance of union. He thought there should be a better result from the action of the Corresponding Societies Committee than from any other agency, and wished that some stronger action had been taken than was indicated in its Report.

Mr. G. P. Hughes said that the Berwickshire Naturalists' Club was doing first-class work in archæology and natural history, but he did not think that federation could be accomplished in the counties of England north of Yorkshire and Lancashire, the area being so large.

The Rev. J. O. Bevan spoke in favour of joint meetings of the Woolhope Naturalists' Field Club, the Cardiff Natural History Society, and the Caradoc and Severn Valley Field Club. It seemed to him that the British Association possessed the best means of leading provincial Societies into union.

Professor Weiss said that the Manchester Microscopical Society was

willing to federate with some of the other Local Societies, and found a desire for affiliation, but a difficulty in carrying it out, many Societies thinking that they would lose more or less of their identity in union. He thought that economy might be effected by original papers being published in journals specially devoted to the branch of science of which they treat, the Local Societies only publishing accounts of their meetings and excursions which would be of interest to all their members.

Mr. W. D. Spanton, while deprecating actual federation, was in favour of joint meetings of the Societies in his district—North Staffordshire.

Mr. R. E. Dodge (New York) mentioned the Scientific Alliance of New York as having accomplished something by union, the announcement of meetings being satisfactorily made in the Bulletin of the Alliance, and the libraries of the different Societies being kept together in one building. At Washington the Joint Commission, on which all the Government scientists are represented, was formed on similar lines.

Dr. Henry M. Ami (Ottawa) said that this question had also arisen in Canada. For two years they had been attempting to bring about the union of the Ottawa Literary Society and the Ottawa Field Naturalists' Club. This club was wasting energy by the publication in the 'Ottawa Naturalist' of non-scientific matter which crowded out scientific papers. There was a movement on foot in Canada to form a Canadian Academy of Science, in which geology, botany, zoology, and microscopy would be represented.

Mr. Hopkinson said that there were various ways in which federation could be carried out, which he might roughly group under three heads—amalgamation, union, and co-operation with representation. He instanced the Caradoc and Severn Valley Field Club as a good example of the benefit of amalgamation, a strong field club doing good local work, and publishing the results, having been formed by the coalition of two Societies which were struggling for existence. The advantages of union without amalgamation were well illustrated by the Yorkshire Naturalists' Union, each Society composing it being quite independent, but meeting together at an annual congress in different Yorkshire towns. Amongst its members were several Yorkshiremen, like himself not now residing in the county nor being members of any of the affiliated Societies. The publications of the Union were devoted to the meteorology, geology, botany, and zoology of Yorkshire. Under the third heading might be cited the present Conference, or such Societies represented as were co-operating with Committees of Research of the British Association; while there were several intermediate links between the three grades of union. Federation, therefore, did not imply sacrifice of individuality.

Section C.

Mr. G. W. Lamplugh called attention to the appointment of a Committee of this Section for obtaining a collection of Canadian Geological Photographs, on the same lines as the British Committee.

SECTION D.

Professor Herdman requested the delegates of Societies located on the coast to give attention to the investigation of green oysters and to the causes which may account for the colour. If oysters were observed to be at all tinged with green, it was desirable to ascertain whether any local conditions, such as the presence of copper mines near the sea, or some other pollution of the water, explained the fact. Professor Herdman said he would be grateful for full details as to any observed cases.

Mr. W. E. Hoyle urged the importance of the accurate use of generic and specific names in the publications of Local Societies. In particular, when naming new species, full and accurate descriptions should always be given.

The second meeting of the Conference was held in the University of Toronto on Monday, August 23. The Corresponding Societies Committee were represented by Sir John Evans, K.C.B., F.R.S., President of the Association, and by Professor Meldola, F.R.S., Chairman, and Mr. John Hopkinson, Secretary of the Conference.

The Chairman said that it was usual, at this second meeting of the delegates, to take the various Sections in alphabetical order, and hear from representatives appointed by the sectional Committees any suggestions they might have to make with regard to the Committees of Research to which the Corresponding Societies could render assistance; but he suggested that they should take advantage of the presence of Professor Miall, President of Section D, who would make some remarks upon a possible line of work in which the representatives of the Local Societies were interested.

Professor Miall then made the following remarks :—'My appearance here this afternoon is due to the fact that Professor Meldola and myself, who visited Niagara on Saturday, fell into conversation upon the work of the Local Societies. Your chairman thought it might be of some use to bring before this meeting, in the form of suggestions, as practical as possible, some portions of our talk at Niagara Falls. The Local Societies carry on a great variety of work, but upon that and upon the special influence of those Societies with regard to scientific investigation I do not intend to offer any remarks. I desire only to bring before you one particular line of inquiry which may be of interest to you, and from which we may perceive how one side of natural history is, as it seems to me, unjustly neglected. I refer to the study of life-histories. We study animals and plants in a great variety of forms; we compile statistics of them, and we collect specimens; but the central point of interest, the life-history of the animal, is neglected.

'It may be thought that this study of life-histories is not specially suited for the amateurs who compose a large part of the Local Societies. It cannot be denied that the work is hard and has special difficulties connected with it, for to prosecute it in an adequate manner involves some

knowledge of anatomy and physiology, and also some acquaintance with the problems of development as well as a considerable power of observation and much enthusiasm. These certainly appear to be large demands, but we cannot expect to get any scientific results of real importance which are not procured at the cost of much labour. The things which lie upon the surface and are easily got at are, as a rule, in the present development of science, not of very great value. If we aim at achieving real scientific results we must expect to have to pay for them both with our time and with our labour.

'If there be anyone here who may think of devoting himself to the study of life-histories, I need hardly say that he has an abundant choice of subjects, even in so narrow and so well worked a country as England. I will ask your permission to take a run over that department of natural history with which I have of late years occupied myself. I refer to the study of insects. Anyone who has occupied himself with promoting the scientific study of insects will, I think, agree with me when I say that almost everything still remains to be done. The insects have been collected and classified, but with rare exceptions their life-histories are still unknown. Let me instance the Lepidoptera and Coleoptera, for the simple reason that they are better known than the rest. We know well their external forms or shapes; the stages of many have been recorded and drawn; and along with these external features we know something about their food-plants, mode of life, and so on; but how their mode of life and peculiarities of structure are interrelated we know not. I think it is a reproach to the naturalists of our generation that they are content to leave the higher knowledge of insects and devote their whole attention to mechanical details.

'As a type of what I am dealing with, let me refer you to the common Diptera. I do not think that more than a dozen out of the vast number of these insects have been thoroughly investigated. It seems that 200 or 300 have been studied, at least superficially, and of these we know more or less; but they are among many thousands of which it seems that we are practically in complete ignorance. What, then, can we expect to learn about such a subject as this unless we are prepared to meet difficulties and incur the cost of time and labour? Here is a vast and important field inviting the attention of naturalists; and when we consider the number of enthusiastic naturalists scattered, not only over our own, but also over every other country, we might surely expect most important results if this business were taken seriously in hand.

'As to the methods of inquiry, let me suppose that any one of you intends to take up live natural history. I should recommend him to study the things which are commonly found round about him; to procure those animals which he is accustomed to see again and again every day, and which he will not have to go a mile or two to procure, say from the nearest stream if not too far away. Then as to the helps which exist, there is a literature of this subject; but one difficulty is that most, if not all, of this literature is written in a foreign language. Malpighi wrote in Latin, and

Swammerdam in Dutch, Réaumur in French, while Boerhaave translated Swammerdam's work into Latin.

'It is singular that so great a lapse of time has taken place with little addition to the literature of this subject, since these writers are of the seventeenth and eighteenth centuries. The work which they carried forward with so much promise of high achievements was allowed to fall into neglect. There are a few exceptions, but, generally speaking, from the commencement of the century up to the present time the subject seems to have fallen into almost complete abeyance.

'To incite beginners to undertake this special work of the study of life-histories, I think that something might be done if we were to put before them a single example of a common insect worked out with some degree of detail. If that were done in England it would get over the difficulty felt by naturalists who have not made acquaintance with a foreign language. We have hardly any examples of life-histories worked out and presented to us in a thoroughly acceptable form. This difficulty seems to me so considerable that I am now trying to draw up such a life-history of the Chironomus, or blood-worm, which is everywhere accessible. It is one of the most instructive insects known to naturalists, and in twelve months I hope to have its life-history ready for the use of the student.

'But it is not enough merely to have a book put into the hands of students; they must know how the actual work of observation is done. It might be possible to pick up from among the members of the Corresponding Societies in various parts of England an enthusiastic party of young men and show them how particular things are done. For instance, how to capture certain kinds of insects, how to study them anatomically, how to disclose the embryonic development and the inner changes which accompany metamorphosis. Let me suppose that out of the members of the Local Societies situated within convenient distance of the city of Leeds, where I have my laboratory, twelve should agree to assemble some time next summer, say in July, and take up the work which I have proposed, each to bring his own microscope, if he has one. I will then undertake to go through a quite elementary course of training on the Chironomus, its life-history and its development. I think I can undertake to initiate such a party of investigators into a useful method of carrying on the study of life-histories, and I think they will carry home with them, from a short course of study, a determination to pursue the work. We could then try the experiment in another district, London for instance; and I should also be glad to do anything by way of correspondence to further this study.

'If we should succeed in carrying out this plan it might lead to a revival of the study of natural history in our country. Each student might turn into a centre of infection when he went home, and spread the virus through his brother naturalists. Let us look forward to such a revival, and if the suggestions which I have made should command for this subject the sympathy it deserves, we may realise a bright future for this important branch of knowledge.'

Sir John Evans expressed the indebtedness of the meeting for the practical suggestions of Professor Miall. He hoped that those present would realise the desirability of extending the work of the Local Societies in the direction indicated. Listening to Professor Miall's plea for the study of the life-histories of insects, he recalled the observation of a great ancient authority, Pliny, who said that the nature of things is nowhere more complete than in the least (*Cum natura rerum nusquam magis quam in minimis tota sit*), a remark which he thought foreshadowed the results discovered by naturalists by means of the microscope in modern times.

The Chairman said that he would like to express the hope that when Professor Miall's suggestions had been circulated among the members of the Corresponding Societies, and his ideas had borne fruit, they would have the pleasure of hearing, at another Conference, of his students having achieved valuable work under his tutorship.

Dr. Ami then read his 'Report on the State of some of the Principal Museums in Canada and Newfoundland,' which was ordered by the General Committee to be printed *in extenso*, see p. 62.

The Chairman said that he could not help being struck with the great wealth of material existing in Canada. Englishmen must feel a certain amount of regret that the museum question is not taken up with more earnestness in their own country. Their provincial museums only existed with much difficulty, and were altogether dependent upon private bounty in carrying on their existence. Anyone who visits many of the local museums in England must see that the museum question has not taken that prominent part in public opinion which it ought to do. Dr. Ami had collected a vast amount of information of great value. There must be in the museums of Canada much valuable material in the way of types, and students in all parts of the world would be the gainers if it were widely known where those types were to be found.

Professor Prince explained that the Fisheries Collection at Ottawa under his charge was made for the Fisheries Exhibition in London in 1883, and was brought back to Canada and given a permanent home. It was scarcely representative of the various fisheries of the Dominion, but it was an interesting collection to anyone coming from the old country, as it represents the waters of a country abounding in ganoids and other remarkable creatures of scientific interest. He considered the Victoria Museum to be a perfect model of its kind.

Professor Meldola then proposed a vote of thanks to Dr. Ami, and

Mr. Hopkinson seconded it, remarking that he was specially interested in the museum question at the present time, for, with other members of the Hertfordshire Natural History Society, including Sir John Evans, he was now endeavouring to raise sufficient money to build and endow a museum for Hertfordshire, for which Earl Spencer had granted an ample site at St. Albans. They had already been promised about 1,500*l.*, but had decided not to commence building until 2,000*l.* had been raised.

A temporary museum had been opened at St. Albans, and he felt sure, from their success in obtaining objects of local interest for it, that if the money required could be raised an interesting and valuable collection would be got together. He feared that Dr. Ami's paper was too long to be published in the Report of the Conference of Delegates, but as the Conference stands upon the same footing as any Section of the Association, it was empowered to suggest to the Committee of Recommendations that this paper was considered of sufficient importance to be published *in extenso* in the Report of the Association, and he moved that this request be made.

The vote of thanks and recommendation were carried unanimously.

Section H.

Professor Haddon, speaking on behalf of the Ethnographic Survey Committee, said that it seemed to him that, while the Local Societies properly spend a great deal of time on natural history, they neglect the study of man, who is an animal, and deserves to be studied as thoroughly as the lower animals. Local Societies might well undertake a survey of the ethnography of their own districts. He would be sorry to draw students away from the study of other branches of natural history, but he thought that there must be many members of the Local Societies who did not study the fauna, the flora, or the geology of their locality, but would be interested in ethnographical work of some kind. There are several anthropological investigations which could be attempted almost anywhere. Besides observations on the colour of the hair and eyes, the stature, the shape of the head, and other physical characters, the customs and beliefs of the people and their folk-lore should be studied. As examples, mention need only be made of local customs on particular days, or the numerous and very interesting singing games of children, such as 'Jenny Jo,' 'Dukes-a-riding,' 'Green Gravel,' and the like. These might seem to be trifling matters, but many such customs and games are the only records we have left to us of the religious rites and social customs of our ancestors, and therefore they are by no means to be despised. It would also be advisable for the local scientific and photographic Societies to interest their members in depicting the geology, natural history, and ethnology of their district, the latter especially. Many opportunities for the study of British anthropology are vanishing or becoming modified, just as surely as are corresponding details in the islands of the Pacific.

The Corresponding Societies of the British Association for 1897–98.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204 George Street, Glasgow. Alex. Ross and D. Dewar	180	None	2*s.* 6*d.*	Annals, occasionally
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5*s.*	10*s.*	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	250	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1862	Belfast Nat. F. C.	Museum, College Square. F. J. Bigger, M.R.I.A.	500	5*s.*	5*s.*	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Dr. J. Hardy, Oldcambus, Cockburnspath, N.B., and Rev. G. Gunn, M.A., Stichill, Kelso, N.B.	400	10*s.* 6*d.*	7*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Mason College, Birmingham. W. P. Marshall and W. Boulton	266	None	1*l.* 1*s.*	Journal, bi-monthly; Proceedings, annually.
Brighton and Sussex Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	Museum, Church Street, Brighton. E. A. Pankhurst.	185	10*s.*	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	Theodore Fisher, M.D., 25 Pembroke Road, Clifton, Bristol	167	5*s.*	10*s.*	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	160	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	Thomas Gibbs, 30 High Street, Burton-on-Trent	200	None	5*s.*	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury.	183	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	456	None	10*s.* 6*d.*	Transactions, half-yearly.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln, and W. F. J. Shepheard	620	None	5*s.*	Annual Report. Proceedings, occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15 Cavendish Street, Chesterfield	381	1*l.* 1*s.* None	Members 31*s.* 6*d.*; Associates and Students 20*s.*	Transactions of Federated Institution of Mining Engineers, about every month.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	270	10*s.* 6*d.*	Minimum, 10*s.* 6*d.*	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	John B. Cornish, Penzance	68	None	1*l.* 1*s.*	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. R. F. Grundy	235	None	10*s.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	355	None	10*s.*	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	Prof. T. Johnson, 12 Gilford Road, Sandymount, Dublin	230	5*s.*	5*s.*	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	E. J. Chinnock, LL.D., Grey Friars', Dumfries	216	2*s.* 6*d.*	5*s.*	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc.	19 Watling Street, Canterbury. Stephen Horsley	83	None	10*s.* 6*d.*	'South Eastern Naturalist,' annually.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, Tylehurst, Kirkcaldy, N.B.	10 Societies, 900 Membs.	None	Assessment of 4*d.* per member	Proceedings, occasionally.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	H. M. Cadell, B.Sc., 5 St. Andrew	150	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.

		[illegible] Hill, Essex				terly and 'Special Memoirs.'
Federated Institution of Mining Engineers	Fed. Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,500	None	None	Transactions, about every month.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Mearns, Glasgow	240	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	S. M. Wellwood, 207 Bath Street, Glasgow	332 Memb. 30 Assoc.	7*s.* 6*d.* None	Members 7*s.* 6*d.* Associates 5*s.*	Transactions and Proceedings, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	John Mayer, 207 Bath Street, Glasgow	640	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually; occasional papers.
Halifax Scientific Society and Geological Field Club, 1874	Halifax S. S. G. F. C.	Literary and Philosophical Society's Rooms. Arthur Crabtree	130	None	2*s.* 6*d.*	'Halifax Naturalist,' every two months.
Hampshire Field Club, 1885	Hants F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7*s.* 6*d.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	John Hopkinson, F.L.S., The Grange, St. Albans	230	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	85	10*s.*	10*s.*	Proceedings, every two or three years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29 High Street, Inverness	160	None	5*s.* and 2*s.*	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	W. Lawson, 35 Molesworth Street, Dublin	100	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Dr. D. Forsyth, 2 Lifton Place, Leeds	90	None	5*s.* and 2*s.* 6*d.*	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	H. B. Wilson, Westfield, Armley, Leeds; W. S. Crowther, 4 Aberdeen Walk, Armley, Leeds	180	None	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. J. M. Gimson	320 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	363	None	Resident 1*l.* 1*s.* Non-Res. and Students 10*s.* 6*d.*	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Chapel Street, Liverpool	690	None	1*l.* 1*s.*	Report, annually; Papers, occasionally.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	53	None	21*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. J. Maxwell McMaster	214	None	1*l.* 1*s.*; Ladies 10*s.* 6*d.*	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Museum, Yorkersgate, Malton, Yorkshire. Rev. S. Jenkinson	85	None	5*s.* and 2*s.* 6*d.*	Science Notes, monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	146	2*s.* 6*d.*	Gentlemen 7*s.* 6*d.* Ladies and Non-Residents 5*s.*	Yn Lioar Manninagh, occasionally.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 16 St. Mary's Parsonage, Manchester	800	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly; 'Geography,' monthly.
Manchester Geological Society, 1838	Manch. Geol. Soc.	5 John Dalton Street, Manchester. James Tonge and Joseph Crankshaw	229	None	1*l.*	Transactions, eight or nine parts per annum.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	E. C. Stump, 16 Herbert Street, Moss Side, Manchester	215	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	63 Brown Street, Manchester. F. E. M. Beardsall and T. Gregory	201	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick	350	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	T. W. H. Mitchell, Mining Offices, Barnsley	259	None	1*l.* 10*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.

CORRESPONDING SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Norfolk and Norwic Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, 3 Oxford Street, Norwich	256	None	5*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,150	None	21*s.* and 42*s.*	Transactions of Federated Institution of Mining Engineers, about every month.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	400	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	H. N. Dixon, M.A., 23 East Park Parade, Northampton	150	None	10*s.*	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Henry Wilkins, 352 Alfreton Road, Nottingham	160	2*s.* 6*d.*	5*s.*	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	342	5*s.*	7*s.* 6*d.*	Report, annually; Meteorological Observations, occasionally.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	Museum, Public Buildings, Penzance. Dr. H. Montgomerie	79	None	10*s.* 6*d.*	Report, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	320	2*s.* 6*d.*	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 105 Freehold Street, Rochdale	243	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	142	None	5*s.*	'Rochester Naturalist,' quarterly.
Scotland, Mining Institute of	Mining Inst. Scot.	James Barrowman, Staneacre, Hamilton, N.B.	479	None	31*s.* 6*d.* and 21*s.*	Transactions of the Mining Institute of Scotland, six times each year
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A. N. H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	580	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	L. Péringuey, South African Museum, Cape Town	88	None	2*l.*	Transactions, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, M. Inst. C.E., 3 Newhall Street, Birmingham	167	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Federated Institution of Mining Engineers, about every month.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. G. E. T. Smithson	1,200	None	10*s.* and 5*s.*	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	Museum, Warwick. S. S. Stanley, 3 Regent Grove, Leamington	90	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	210	10*s.*	10*s.*	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, F.G.S., Hopton, Mirfield	165	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., 259 Hyde Park Road, Leeds	457 and 2,567 Associates.	None	Members 10*s.* 6*d.*; Associates 1*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc.	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	450	None	2*l.*	Report, annually.

Index of the more important Papers, and especially those referring to Local Scientific Investigations, published by the above-named Societies during the year ending June 1, 1897.

*** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Andson, Rev. W.	Meteorology of Dumfries, 1895	Dum. Gal. N. H. A. Soc.	*Trans.*	12	31–37	1897
" "	Meteorological Observations at Warmanbie	" " "	"	"	130–132	"
Barcroft, Joseph	The Properties of the Surface of Liquids (Lecture)	Belfast N. H. Phil. Soc.	*Report & Proc.*	1895–96	24–26	1896
Black, W. G.	Captain Cook's Voyages, 1772–1780: Logs in Three Oceans; Ocean Rainfall	Manch. Geog. Soc.	*Journal*	XII.	198–200	1897
Blythswood, Lord.	The Production of X Rays by an Electric Discharge in the Open Air	Glasgow Phil. Soc.	*Proc.*	XXVII.	160–161	1896
Bottomley, Dr. J. T.	The Discoveries of Hertz, Lenard, and Röntgen about the Electric Luminosity of Vacuum Tubes	" "	"	"	156–160	"
Boys, Rev. H. A., & C. A. Markham	Meteorological Report and Observations	N'ton. N. H. Soc.	*Journal*	IX.	33–39 62–69 109–115	" " "
Buchan, Dr. Alex.	The Ben Nevis Observatories and the Work done there	Glasgow Phil. Soc.	*Proc.*	XXVII.	165–181	"
Cambridge, Rev. O. P.	On a Whirlwind at Bloxworth	Dorset N. H. A. F. C.	"	XVII.	76–79	"
Campbell-Baynard, F.	The Daily Rainfall of Croydon and District for 1895	Croydon M. N. H. C.	*Trans.*	1895–96	203–207 & App.	"
Chancellor, F.	Rainfall in Chelmsford, January to July 1896, compared with Average for twenty-eight Years	Essex F. C.	*Essex Naturalist*	IX.	232	"
Clark, J. Edmund.	Note on the January High Barometer	Yorks. Phil. Soc.	*Report*	For 1896	36, 37	1897
Cole, William	Earth Noises and supposed Slight Earthquake at Mersea and Colchester	Essex F. C.	*Essex Naturalist*	IX.	230–231	1896

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Cresswell, Alfred	Records of Meteorological Observations taken at the Observatory of the Birmingham and Midland Institute	Birm. N. H. Phil. Soc.	*Proc.*	X.	33–64	1896
Eaton, H. S.	Report on the Rainfall in Dorset during 1895	Dorset N. H. A. F. C.	*Proc.*	XVII.	210–221	"
Evans, F. G.	The Meteorology and Kindred Phenomena of 1895	Cardiff Nat. Soc.	*Trans.*	XXVIII.	24–49	"
Gibson, Edward	A 'Bolide,' or Globular Lightning Discharge, at Hatfield Peverel	Essex F.	*Essex Naturalist*	IX.	231–232	"
Greenwood, W. N.	Unification of Time and Navigation	Manch. Geog. Soc.	*Journal*	XI.	248–254	"
Grubbe, Thomas B.	The Weather of 1896 from the Farmer's Point of View	Essex F. C.	*Essex Naturalist*	X.	62–63	1897
Harris, D. F.	Ives' Stereophotochromoscope: A New Optical Instrument	Glasgow Phil. Soc.	*Proc.*	XXVII.	14–19	1896
Hopkinson, John	Hertfordshire Rainfall, Percolation, and Evaporation	Herts N. H. Soc.	*Trans.*	IX.	33–72	"
" "	Meteorological Observations taken at The Grange, St. Albans, during the year 1895	" "	"	"	85–92	"
" "	Climatological Observations taken in Hertfordshire in the year 1895	" "	"	"	93–96	"
" "	Report on the Rainfall in Hertfordshire in the year 1895	" "	"	"	109–120	"
Hurnard, S. F., & F. Chancellor	Rainfall at Lexden (near Colchester) and at Chelmsford in 1896	Essex F. C.	*Essex Naturalist*	IX.	264	1897
Lodge, Prof. O. J.	Modern Views of Light	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	85–99	1896
Macintyre, Dr. J.	Simple Apparatus for X-ray Photography	Glasgow Phil. Soc.	"	XXVII.	161–164	"
McLandsborough, J., & A. E. Preston	Meteorology of Bradford for 1891, 1892, 1893, 1894, and 1895	Yorks. Nat. Union	*Trans.*	20	Ten sheets.	"
Macmuldrow, W. G. P.	Some Instruments used in Measuring and Recording Electric Energy and Electricity	Liv'pool E. Soc.	"	XVII.	113–122	"
Markham, C. A.	The Great English Earthquake, December 17, 1896	N'ton. N. H. Soc.	*Journal*	IX.	151–155	1897
" "	Meteorological Report and Observations	" "	"	"	156–160	"
Mawley, Edward	Report on Phenological Phenomena observed in Hertfordshire during the year 1895	Herts N. H. Soc.	*Trans.*	IX.	97–103	1896

Nicholson, W. A.	High Tide on the East Coast, May 16, 1895	Norf. Norw. Nat. Soc.	*Trans.*	VI.	224–225	1896
Omond, R. T.	Life and Observing at the Ben Nevis Observatory	Glasgow Phil. Soc.	*Proc.*	XXVII.	182–187	"
Parsons, Dr. H. F.	Some further Observations on Earth Temperatures	Croydon M. N. H. C.	*Trans.*	1895–96	175–179	"
Percy, R. F.	The Determination of, and Use of, the Magnetic Meridian in Mine-surveying	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	XII.	581–584	1897
" "	An Improved Protractor	" "	" "	"	585–586	"
Preston, A. W.	Meteorological Notes, 1895	Norf. Norw. Nat. Soc.	*Trans.*	VI.	190–196	1896
Report of Council	The Weather in 1896, Yorkshire	Yorks. Phil. Soc.	*Report*	For 1896	xii.–xv., xviii.–xxiii., 44	1897
Rouse, Martin L.	The Musical Nature of Speech	Brighton N. H. Phil. Soc.	"	1895–96	28–32	"
Ryves, Rev. G. T.	Sectional Report—Meteorology (the Weather of 1895)	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	94–100	1896
Sayers, W. B.	Domestic Applications of Electricity	Glasgow Phil. Soc.	*Proc.*	XXVII.	117–121	"
Southall, H.	Heat and Drought in March, 1893	Woolhope N. F. C.	*Trans.*	1893–94	5–6	"
" "	The Great Drought of 1893	" "	"	"	148–152	"
Thompson, Beeby.	Supernumerary Rainbows	N'ton N. H. Soc.	*Journal*	IX.	41–46	"
Wells, James G., and T. Gibbs	The Weather of 1894 and 1895	Burton N. H. Arch. Soc.	*Trans.*	III.	169–176	"
Whiteley, J.	Weather in Halifax during the year 1896	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	99–101	1897
Whitmell, C. T.	The Moon as a View-point	Cardiff Nat. Soc.	*Trans.*	XXVIII.	6–15	1896
Wragge, Clement.	Meteorology of Queensland	Manch. Geog. Soc.	*Journal*	XII.	128–136	1897

Section B.—CHEMISTRY.

Andrew, Rev. J.	The Primeval Basis and Progressive Build of the Inorganic World	Belfast Nat. F. C.	*Report and Proc.*	IV.	362–379	1897
Clowes, Prof. F.	The Detection and Estimation of Carbon Monoxide in the Air by the Flame Cap Test	Fed. Inst. Min. Eng.	*Trans.*	XIII.	71–73	"
Coquillion, J.	Determination of Fire-damp in French Collieries	" "	"	"	65–68	"
Ferguson, Prof. J.	Dr. Hermann Kopp as Historian of Chemistry (Presidential Address)	Glasgow Phil. Soc.	*Proc.*	XXVII.	1–13	1896
Golding, John	Pot Culture; or, a Method of Studying the Growth of Plants, with an Account of some of the Discoveries that have been made by it	Nott. Nat. Soc.	*Report.*	44	13–22	"
Groves, Thomas B.	Water Analysis a Hundred Years Ago	Dorset N. H. A. F. C.	*Proc.*	XVII.	141–145	"

Section B.—CHEMISTRY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Haldane, J. S.	Investigations on the Nature and Sources of the Suffocative Gas met with in Wells, together with further Observations on the Black Damp of Coal Mines	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XI.	265–273	1896
"	The Causes of Death in Colliery Explosions	Midland Inst. Eng.	" "	"	502–513	"
Hall, H.	Some Aspects of recent Colliery Explosions	N. Eng. Inst.	" "	"	526–534	"
" "	The Cost and Efficiency of Safety Explosives as Compared with Gunpowder	Fed. Inst. Min. Eng.	" "	XIII.	4–21	1897
Howard, David	The Water Supply of the Lea Valley viewed in the Light of recent Researches (Address)	Essex F. C.	*Essex Naturalist*	X.	150–157	"
Orsman, W. J.	Notes on the Explosion of Coal Dust	N. Eng. Inst.	*Trans. Fed. Inst.*	XI.	536–539	1896
Ramsay, Prof. Wm.	Argon and Helium (Graham Lectures)	Glasgow Geol. Soc.	*Proc.*	XXVII.	92–108	"
Sexton, Prof. A. H.	The By-products of the Blast-furnace	" "	"	XXVII.	122–135	"
Stuart, D. M. D.	The Phenomena of Colliery Explosions	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XII.	371–381	1897
Winkhaus, F.	Further Experiments with Explosives	N. Eng. Inst.	" "	"	32–49	1896
" "	The Danger of Employing Safety Fuses for Blasting in Fiery Mines	"	" "	"	169–176	"

Section C.—GEOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Anderson, James	Evidences of the most recent Glaciers in the Firth of Clyde District	Glasgow Geol. Soc.	*Trans.*	X.	198–209	1896
Barke, F.	Sectional Report—Geology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	79–84	"
Beasley, H. C.	Classification of the Footprints from the Trias in Cheshire and Lancashire	Liv'pool Geol. Soc.	*Proc.*	VII.	391–409	"
Bell, Alfred	A Synopsis of the Crustacea and Echinodermata of the Upper Tertiaries	Yorks. Phil. Soc.	*Report*	For 1896	1–12	1897
Bell, Dugald	On the High-level Shelly Deposits, and their bearing on the Question of Submergence, with Special Reference to the recent (Third) Edition of Dr. James Geikie's 'Great Ice Age.'	Glasgow Geol. Soc.	*Trans.*	X.	346–348	1896
Bergeron, J.	Possible Extensions of the Coalfields of France	Fed. Inst. Min. Eng.	"	XII.	335–357	1897
Bladen, W. Wells	On the Osseous and other Remains found at Stone	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	108–115	1896

	Sheffield					
Brady, F., G. P. Simpson, and Nath. R. Griffith	The Kent Coalfield	N. Eng. Inst.	*Trans. Fed. Inst.*	XI.	540–550	„
Brodie, Rev. P. B.	On the Sandstones in the Upper Keuper in a part of Warwickshire six miles north-west of Warwick	Warw. N. A. F. C.	*Proc.*	41	36–39	1897
Bunkell, H. B.	Notes on the Venterskroom Goldfields, South African Republic	N. Eng. Inst.	*Trans. Fed. Inst.*	XII.	186–189	1896
Callaway, Dr. C.	A Sketch of the Process of Metamorphism in the Malvern Crystallines	Liv'pool Geol. Soc.	*Proc.*	VII.	453–460	„
Campbell, Rev. Jos.	The Goldfields of the Hauraki Peninsula, New Zealand	N. Eng. Inst.	*Trans. Fed. Inst.*	XII.	462–482	1897
Churchill, J. M.	The Geology of Pontypool	Cardiff Nat. Soc.	*Trans.*	XXVIII.	98–103	„
Close, Rev. M. H.	The former Abundance of Granite Boulders in the south-east Neighbourhood of Dublin	Dublin N. F. C.	*Irish Naturalist*	VI.	29–33	„
Coates, Henry	Annual Address (Scenes in the Geological History of the Site of Perth)	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	cvii.-cx.	1896
Coke, G. E.	Southern Limit of the Nottinghamshire Coalfield	Fed. Inst. Min. Eng.	*Trans.*	XI.	339–341	„
Cole, Prof. G. A. J.	Oldhamia in America	Dublin N. F. C.	*Irish Naturalist*	V.	254–255	„
„ „	A Proposed Geological Photographic Survey of the Counties of Dublin and Wicklow	„ „	„ „	VI.	125–126	1897
Collins, J. H.	Notes on Cornish Fossils	Cornw. R. Geol. Soc.	*Trans.*	XII. Pt. II.	65–70	„
Cooke, John H.	Work for Lincolnshire Geologists	Yorks. Nat. Union	*The Naturalist*	For 1896	205–210	1896
„ „	A Section in the Lower Oolites of Scarborough	„ „	„ „	„	289–292	„
„ „	Lincolnshire Boulders	„ „	„ „	For 1897	103–105	1897
Craig, Robert	Remarks upon 'Joints' or Natural Fractures in Limestones	Glasgow Geol. Soc.	*Trans.*	X.	210–215	1896
De Rance, C. E.	Notes on the Geological Features of the Coast of North Wales from Liverpool to Menai Bridge	N. Eng. Inst.	*Trans. Fed. Inst.*	XI.	552–555	„
„ „	The River Weaver and its Salt Beds	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	128–129	„
Dickson, E., and P. Holland	Analyses of Triassic Rocks from the Neighbourhood of Liverpool	Liv'pool Geol. Soc.	*Proc.*	VII.	443–452	„
Dunston, George	The Eastern Extension of the Midland Coalfield and the Exploration at Southcar	Midland Inst. Eng.	*Trans. Fed. Inst.*	XII.	515–2 2	„
Fisher, Rev. Osmond	The Geology of the Portesham District	Dorset N. H. A. F. C.	*Proc.*	XVII.	194 – 9	„
Geikie, Sir A.	The Latest Volcanoes of the British Isles	Glasgow Geol. Soc.	*Trans.*	X.	179 –9	„
Gibson, Walcot	The Geology of Africa in relation to its Mineral Wealth	Fed. Inst. Min. Eng.	„	XII.	303–322	1897

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Gray, William	The Origin and Present Condition of the Giant's Causeway	Belfast N. F. C.	*Report and Proc.*	IV.	357–362	1897
Grensted, Rev. F. F.	The Dynamical Theory of the Craven Highlands	Liv'pool Geol. Soc.	*Proc.*	VII.	377–383	1896
Gresley, W. S.	The Yorkshire and Nottinghamshire Coalfield: Geological Suggestions relative to its eastward Extension beneath the Permian and Secondary Strata into Lincolnshire	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	XI.	143–153	„
Harker, Alfred	In Memoriam: Alexander Henry Green	Yorks. Nat. Union	*The Naturalist*	For 1897	111–114	1897
Harrison, Rev. S. N.	Report of Geological Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	120–121	1896
Holmes, T. V.	A Sketch of the Geology of Epping Forest	Essex F. C.	*Essex Naturalist*	IX.	160–165	„
„ „	Notes on the Ancient Physiography of South Essex	„ „	„ „	„	193–200	„
„ „	The Relation of Palæolithic Man to the Glacial Epoch	„ „	„ „	„	245–247	1897
„ „	The Palæolithic Deposits at Hitchin, and their Relation to the Glacial Epoch (Report to the Royal Society by Mr. Clement Reid)	„ „	„ „	X.	49–51	„
Howard, F. T.	An Ichthyosaurus Jaw from the Lias of Lower Penarth	Cardiff Nat. Soc.	*Trans.*	XXVIII.	71–72	1896
„ „	A Deep Well Boring (1,063 feet) at Cardiff Docks	„ „	„	„	72–74	„
„ „	The Geology of the East Barry Dock, with Notes on the supposed Coalfields of South Glamorgan	„ „	„	„	77–89	1897
Howard, F. T., and Evan W. Small	Geological Notes on Skomer Island	„ „	„	„	55–60	1896
Howard, F. T., and T. H. Thomas	Note on Eophrynus found at Ty'nybedw by W. O'Connor	„ „	„	„	52–54	„
Jeffs, Osmund W.	The Origin and Characteristics of our British Scenery	Manch. Geog. Soc.	*Journal*	XI.	265–266	„
Jukes - Browne, A. J.	On a Collection of Fossils from the Upper Greensand in the Dorset County Museum	Dorset N. H. A. F. C.	*Proc.*	XVII.	96–108	„
Kincaid, James	Coal: Its Origin and Use (Lecture)	Buchan F. C.	*Trans.*	IV.	17–19	1897
Landon, Joseph	Underground Water Channels	Birm. N. H. Phil. Soc.	*Journal*	II.	83–86	„
La Touche, Rev. J. D.	Further Notes on the Geology of the Brown Clee District	Woolhope N. F. C.	*Trans.*	1893–94	15–19	1896

	and Klerksdorp Districts)					
Lomas, J.	Observations on recent Glacial Striæ in Switzerland	Liv'pool Geol. Soc.	*Proc.*	VII.	383–387	„
Longridge, Capt. C. C.	Mining in Northern Argentina	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XII.	327–334	1897
Louis, Henry	Note on the Tellurium Mineral of Choukpazat	N. Eng. Inst.	„ „	„	513	„
McLennan, J. S.	The Coast Line of Berwickshire from Eyemouth to Marshall Meadows Bay	Glasgow Geol. Soc.	*Trans.*	X.	337–345	1896
Macnair, Peter	On the Altered Basic Rocks of the Highlands as exemplified by the Sill of Hornblende Schist underlying the Loch Tay Limestone	„ „	„	„	302–317	„
Mansel - Pleydell, J. C.	On the Footprints of a Dinosaur (Iguanodon ?) from the Purbeck Beds of Swanage	Dorset N. H. A. F. C.	*Proc.*	XVII.	115–122	„
Marshall, J. W. D.	Notes on the British Brachiopoda: Part I.	Bristol Nat. Soc.	„	VIII.	17–40	„
Meacham, F. J.	Bumps and Outbursts of Coal	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	XII.	612–615	1897
Metcalfe, A. T.	The Gypsum Deposits of Nottinghamshire and Derbyshire	Chesterf. Mid. Count. Inst.	„ „	„	107–114	1896
„ „	The Tertiary Lava Fields of the West Coast of Scotland	Nott. Nat. Soc.	*Report*	44	1–12	„
Meyrick, E.	List of Cretaceous Fossils of the Marlborough District	Marlb. Coll. N. H. Soc.	„	45	55–57	1897
Millett, F. W.	The Foraminifera of the Pliocene Beds of St. Erth in relation to those of other Deposits	Cornw. R. Geol. Soc.	*Trans.*	XII. Pt. II.	43–46	„
Mitchell, D. J.	The Greensand at Moreseat	Buchan F. C.	„	IV.	30–32	„
Neilson, James	On the Occurrence of Marine Organisms in the Boulder Clay of the Glasgow District. Part I.	Glasgow Geol. Soc.	„	X.	278–279	1896
„ „	„ „ „ Part II.	„ „	„	„	273–277	„
„ „	On the Old Red Sandstone and Carboniferous Rocks of the North End of the Island of Arran	„ „	„	„	280–301	„
Newby, John R.	The Earthquakes in Iceland, 1896	Manch. Geog. Soc.	*Journal*	XII.	174–187	1897
O'Conncr, W.	On several Fossils, including a 'Spider' (*Eophrynus*) from the 9-foot Coal Seam at Ty'nybedw, Rhondda Valley	Cardiff Nat. Soc.	*Trans.*	XXVIII.	50–52	1896
Parsons, Cyril E.	The Deposit at the Mill Close Lead Mine, Darley Dale, Matlock	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	XII.	115–121	„
Piper, G. H.	Geology of the District near Ledbury	Woolhope N. F. C.	*Trans.*	1893–94	22–23	„
Polwhele, T. R.	Anniversary Address	Cornw. R. Geol. Soc.	„	XII. Pt. II.	9–18	1897

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Praeger, R. Ll.	A Submerged Pine Forest	Dublin N. F. C.	*Irish Naturalist*	V.	155–160	1896
Pratt, Dr. R.	A Visit to the Upper Cretaceous System at Eastbourne	Leicester Lit. Phil. Soc.	*Trans.*	IV.	258–266	"
Prentice, James	The Mineral Seams of New Monkland	Mining Inst. Scot.	"	XVIII.	37–51	"
Preston, Henry	Some Account of the Surface Geology of the District North of Grantham	Yorks. Nat. Union	*The Naturalist*	For 1896	285–288	"
Reade, T. Mellard	Presidential Address: British Geology in relation to Earth Folding and Faulting	Liv'pool Geol. Soc.	*Proc.*	VII.	363–377	"
" "	Foraminiferal Boulder Clay at Great Crosby, and at Blackpool	" "	"	"	387–390	"
" "	The Drift of the Mid-Wales Coast	" "	"	"	410–419	"
" "	The Berwickshire Coast: a Study in Physical Geology	" "	"	"	420–443	"
Reid, James, and Peter Macnair	On the Genera *Lycopodites* and *Psilophyton* of the Old Red Sandstone Formation of Scotland	Glasgow Geol. Soc.	*Trans.*	X.	323–330	"
Roberts, S.	The Submarine Forest Bed at Maenporth, near Falmouth	Cornw. R. Geol. Soc.	"	XII. Pt. II.	58–64	1897
Sharman, G., and E. T. Newton	Cretaceous Fossils from the Drift of Moreseat, Aberdeen	Buchan F. C.	"	IV.	26–30	"
Sheppard, Thos.	Notes on the Occurrence of Boulders of Shap Granite, &c., in Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1896	333–339	1896
" "	Lincolnshire Boulders	" "	" "	"	373	"
Simpson, William	Some Physiographical and Geological Features of the Parish of Halifax	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	{2–6, 26–29}	"
" "	The Strata of the Parish of Halifax	" "	" "	"	69–77	"
Smith, John	A New View of the Arran Granite Mountains	Glasgow Geol. Soc.	*Trans.*	X.	216–256	"
" "	Charred Coal with Graphite, and Discovery of Diamonds in the Graphite at Craigman, New Cumnock	" "	"	"	257–262	"
" "	On the Discovery of Fossil Microscopic Plants in the Fossil Amber of the Ayrshire Coalfield	" "	"	"	318–322	"
" "	Dry River Channels in the Neighbourhood of Muirkirk	" "	"	"	331–333	"
" "	On the Occurrence of Pumice Pebbles in the	" "	"	"	349–353	"

Stanley, S. S.	The Origin of Gravel Beds, illustrated in some Local Drifts	Warw. N. A. F. C.	*Proc.*	41	15–19	1897
Stephens, Francis J.	The Morte Slates, as described by Dr. Hicks	Cornw. R. Geol. Soc.	*Trans.*	XII. Pt. II.	47–48	„
„ „	On an Altered Ashbed at Penryn	„ „	„	„	49–57	„
Tate, Thomas	The Yorkshire Boulder Committee and its Tenth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1897	59–74	„
Thompson, Beeby	Pre-Glacial Valleys in Northamptonshire	N'ton. N. H. Soc.	*Journal*	IX.	47–50	1896
„ „	The Junction Beds of the Upper Lias and Inferior Oolite in Northamptonshire	„ „	„	„	73–80, 131–149	„ 1897
„ „	Ichthyosaurus from Corby	„ „	„	„	80–81	„
Tuckwell, Rev. W.	The Lincolnshire Naturalists' Union Boulder Committee	Yorks. Nat. Union	*The Naturalist*	For 1896	349–353	1896
Wardle Thomas	The Geology of Cromer	N. Staff. N. F. C. A. Soc.	*Report & Trans.*	XXX.	134–143	„
Whitaker, Wm.	Some Essex Well-sections (Part IV.), with some Water Analyses	Essex F. C.	*Essex Naturalist*	IX.	167–190	„
Whitaker, Wm., & T. V. Holmes	Borings in Search of Coal in Suffolk and Essex	„ „	„ „	„	213–218	„
„ „	Boring in Search of Coal at Weeley, in Essex	„ „	„ „	„	253–255	1897
„ „	Boring in Search of Coal in Essex—Reports	„ „	„ „	X.	9–10	„
Wotton, F. W.	The Fauna and Flora of the Shell-bed Deposits at East Barry Dock	Cardiff Nat. Soc.	*Trans.*	XXVIII.	90–93	„
Wright, Joseph	Boulder Clay, a Marine Deposit. Part I.	Glasgow Geol. Soc.	„	X.	263–269	1896
„ „	„ „ Part II.	„ „	„	„	270–272	„
Young, Dr. John	Notes on the Ostracoda found in the Lacustrine, or Freshwater, Strata of the Campsie District, which alternate with the Lower Beds of the Carboniferous Marine Limestone Series	„ „	„	„	334–336	„

Section D.—Zoology.

Adams, Lionel E.	*Limax maximus*, L., var. *alba*, nov. in Northamptonshire. (New to Britain.)	N'ton. N. H. Soc.	*Journal*	IX.	60	1896
„ „	*Limax marginatus* (Müll.) in Northamptonshire	„ „	„	„	„	„
„ „	*Amalia gagates* (Draparnaud) in Northamptonshire	„ „	„	„	„	„
„ „	The Mammalian Fauna of Northamptonshire	„ „	„	„	117–130	1897

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Ashdown, W. C.	Ornithology in Herefordshire in 1894	Woolhope N. F. C.	*Trans.*	1893–94	258–259	1896
Backhouse, James	The Little Owl in Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1897	76	1897
Bates, F.	The Coleoptera of Bradgate Park	Leicester Lit. Phil. Soc.	*Trans.*	IV.	170–176	1896
Benson, Rev. C. W.	The Icterine Warbler	Dublin N. F. C.	*Irish Naturalist*	VI.	117–119	1897
Birtwhistle, A.	Sums paid for Fox heads or other Vermin from the Skipton Churchwardens' Account 1729–1830	Yorks. Nat. Union	*The Naturalist*	For 1896	259–270	1896
Bladen, W. Wells	The Cuckoo and its Foster Parents	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	23–39	"
Bouskell, Frank	The Disappearance of certain Species of Insects, with Notes on their Slaughter and Protection	Leicester Lit. Phil. Soc.	*Trans.*	IV.	267–275	1897
Bridge, Prof. T. W.	The Tuatara Lizard (*Sphenodon punctatum*) of New Zealand	Birm. N. H. Phil. Soc.	*Journal*	II.	65–66	1896
Brodie, Rev. P. B.	Presidential Address (Palæontology, &c.)	Warw. N. A. F. C.	*Proc.*	41	1–14	1897
Broom, Dr. R.	On some Australian Mammals	Glasgow N. H. Soc.	*Journal*	IV.	351–354	"
Cambridge, Rev. O. P.	On New and Rare British Spiders observed in 1895	Dorset N. H. A. F. C.	*Proc.*	XVII.	55–63	1896
Carpenter, G. H.	Irish Animals in the Dublin Museum	Dublin N. F. C.	*Irish Naturalist*	VI.	127–131	1897
Carter, J. W.	Some Cockroaches found at Bradford	Yorks. Nat. Union	*The Naturalist*	For 1897	26	"
Chapman, Dr. T. A.	The Genus *Acronycta* and its Allies	Woolhope N. F. C.	*Trans.*	1893–94	61–119	1896
" "	On the Larva of *Arctia caia*	" "	"	"	206–218	"
Christy, Miller	On an Early Record of the Occurrence of the Narwhal (*Monodon monoceros*) on the Coast of Norfolk	Norf. Norw. Nat. Soc.	"	VI.	204–207	"
Clarke, H. S.	Report of the Entomological Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	124–127	"
Coates, Henry	Opening Address (On the Work of the Society during the Year 1895)	Perth Soc. N. Sci.	*Trans. & Proc.*	II.	lxx.-lxxviii.	"
Cole, William	The Protection of Wild Birds in Essex	Essex F. C.	*Essex Naturalist*	IX.	255–258	1897
" "	The Birds in Epping Forest	"	" "	X.	56–57	"
Cordeaux, John	Occurrence of Macqueen's Bustard in East Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1896	323–324	1896
" "	Bird Notes from the Humber District. Autumn of 1896	" "	" "	For 1897	13–18	1897
Crellin, John C.	Report of Zoological Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	122–124	1896
Crossman, Alan F.	Birds observed in Hertfordshire during the	Herts. N. H. Soc.	*Trans.*	IX.	73–84	"

C. T.	ptera in South Norfolk and North Suffolk: a comparison between Broadland and Fen	Leicester Lit. Phil. Soc.	*Trans.*	IV.	219–224	,,
Dalgleish, John J.	List of Birds which have been observed in the District of Ardnamurchan, Argyllshire, with Additions thereto, and Notes	Glasgow N. H. Soc.	*Journal*	,,	347–350	1897
Daltry, Rev. T. W.	Sectional Report—Entomology:	N. Staff. N. F. C. A. Soc.	*Report & Trans.*	XXX.	58–64	1896
Davis, W. F. W.	The Dipper (*Cinclus aquaticus*)	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	29	,,
Day, G. Morland	Some Fishes of the District	Burt. N. H. Arch. Soc.	*Trans.*	III.	111–117	,,
Donisthorpe, H. St. J.	The Coleoptera of Weymouth and Neighbourhood	Leicester Lit. Phil. Soc.	,,	IV.	330–337	1897
Donnon, Dr. W. D.	Fresh-water Algæ	Belfast Nat. F. C.	*Report and Proc.*	IV.	380–381	,,
Drane, R.	Notes on the Natural History of the Islands Skomer, the Stack Rock, and St. George's Island, near Looe	Cardiff Nat. Soc.	*Trans.*	XXVIII.	61–70	1896
Drummond-Hay, Col. H. M. (the late)	Museum Notes: On the Nests of Birds of Perthshire and the Basin of the Tay	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	143–147	,,
Duerden, J. E.	Notes on the Rock Pools of Bundoran	Dublin N. F. C.	*Irish Naturalist*	V.	153–155	,,
Duthie, Lieut.-Col. W. H. M.	Notes on the Nesting of British Birds	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	137–143	,,
Elliott, J. Steele	The Vertebrate Fauna of Sutton Coldfield Park	Birm. N. H. Phil. Soc.	*Journal*	,,	48–54, 58–63, 69–73	,,
Emerson, P. H.	Migration Notes from Lowestoft	Norf. Norw. Nat. Soc.	*Trans.*	VI.	227	,,
Enock, Frederick	Discovery of the Male of *Prestwichia aquatica* in Epping Forest	Essex F. C.	*Essex Naturalist*	X.	10–11	1897
Fielding, Rev. C. H.	Our River Fish	Rochester N. C.	*Roch. Naturalist*	II.	411–417	,,
Flower, Sir W. H.	On the Educational Value of Museums	Perths. Soc. N. Sci.	*Trans. and Proc.*	,,	lxxxi.–lxxxviii	1896
Forrest, H. E.	Sponges: their Structure and Affinities (Lecture)	Car. & Sev. Vall. F. C.	*Trans.*	I.	146–154	1897
,, ,,	Life in the Depths of the Sea (Lecture)	,, ,,	,,	,,	190–192	
Fowler, Rev. Canon W. W.	Presidential Address to the Lincolnshire Naturalists' Union	Yorks. Nat. Union	*The Naturalist*	For 1897	149–156	,,
Fryer, Dr. A. C.	Bookworms found in America	Bristol Nat. Soc.	*Proc.*	VIII.	46–47	1896
Gibbs, A. E.	Lepidoptera observed in Hertfordshire during the year 1895	Herts N. H. Soc.	*Trans.*	IX.	27–32	,,
Gibbs, T.	The Larva of the Eel	Burt. N. H. Arch. Soc.	,,	III.	155–157	,,
Gill, Deemster	Report as Delegate to British Association Meeting at Ipswich	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	,,	87–92	,,

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Goodman, C. H.	Notes on the House-cricket (*Acheta domestica*)	Croydon M. N. H. C.	*Trans.*	1895-96	199–203	1896
Goulding, R. W.	Lincolnshire Naturalists at Grantham	Yorks. Nat. Union	*The Naturalist*	For 1896	273–276	"
Grabham, Oxley	Owls and their Longevity	" "	" "	For 1897	129–132	1897
" "	The Harvest Mouse in Yorkshire	" "	" "	"	177–178	"
Gurney, J. H.	The New Zealand Owl (*Sceloglaux albifacies*, Gray) in Captivity	Norf. Norw. Nat. Soc.	*Trans.*	VI.	154–158	1896
Halbert, J. N.	Insects collected on Lugnaquilla and in Glenmalur Valley, co. Wicklow	Dublin N. F. C.	*Irish Naturalist*	V.	210–212	"
Hall, A. E.	Yorkshire Lepidoptera for 1891	Yorks. Nat. Union	*Trans*	20	141–146	"
Halliday, Edward.	The Butterflies of Halifax	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	19	"
Harding, George	Additions and Corrections to Local List of Lepidoptera	Bristol Nat. Soc.	*Proc.*	VIII.	55–59	"
Harries, H. F.	British Birds (Seventh Lecture)	Car. & Sev. Vall. F. C.	*Trans.*	I.	161–164	1897
" "	The Birds of the Shetland Islands (Lecture)	" "	"	"	188–189	"
Hey, Rev. W. C.	List of the Coleoptera of Yorkshire (continuation)	Yorks. Nat. Union	"	20	65–96	1896
Hodson, Rev. J. H.	The Life Story of a Blue Bottle	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	41–45	"
Hopkinson, John	Report on the Conferences of Delegates to the British Association at Oxford in 1894	Herts N. H. Soc.	*Trans.*	VIII.	xli–xlviii	"
Hotblack, J. T.	*Mus rattus* at Yarmouth	Norf. Norw. Nat. Soc.	"	VI.	229, 230	"
Hutchinson, Thos.	The Wolf in Britain	Woolhope N. F. C.	"	1893–94	252–256	"
Jameson, H. L.	The Bats of Ireland	Dublin N. F. C.	*Irish Naturalist*	VI.	34–43	1897
Kane, W. F. de V.	Further Observations on the Development of Melanism in Moths	" "	" "	"	44	"
" "	*Leucania unipuncta*, Haw., in Co. Cork	" "	" "	"	104	"
Kelsall, Rev. J. E.	The Reptiles of Hampshire and the Isle of Wight	Hants F. C.	*Proc.*	III.	267–273	"
Kew, H. Wallis	The Land Planarian, *Rhynchodemus terrestris* (Müll.), in Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1897	106	"
Kropotkin, Prince	Mutual Aid amongst Animals (Anniversary Address)	Herts N. H. Soc.	*Trans.*	IX.	1–13	1896
Lilford, Lord	Notes on the Ornithology of Northamptonshire and Neighbourhood for 1895	N'ton N. H. Soc.	*Journal*	"	1–16	"
Lovett, Edward	The Protective Methods of certain Larvæ	Croydon M. N. H. C.	*Trans.*	1895–96	184–186	"
McGregor, T. M.	Natural History Studies by the Boys' Brigade Field Club at Ballinluig	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	133–137	"

Martin, Howard	Oysters	Croydon M. N. H. C.	*Trans.*	1895–96	194–198	„
Masefield, J. R. B.	Sectional Report: Zoology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	44–52	„
„ „	Life in the Hotwater Reservoir at the Tape Mill, Cheadle, Staffordshire	„ „	„ „	„	53–57	„
Mason, J. E.	Some Diptera of the Alford District, North Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1896	175–180	„
Mason, Philip B.	The Struggle for Life in the Individual and Community (Presidential Address, 1894)	Burt. N. H. Arch. Soc.	*Trans.*	III.	137–154	„
Mayfield Arthur	The Mollusca of Norfolk	Norf. Norw. Nat. Soc.	„	VI.	185–189	„
Meade, R. H.	Gossip on Natural History	Yorks. Nat. Union	*The Naturalist*	For 1896	253–256	„
Meyrick, E.	List of Vertebrate Animals (except Birds) of the Marlborough District	Marlb. Coll. N. H. Soc.	*Report*	45	38–42	1897
„ „	Observations on Insects near Marlborough	„ „	„	„	75–88	„
„ „	Observations on Birds	„ „	„	„	89–93	„
Mottram, James	Memoir of the late Frederic Kitton	Norf. Norw. Nat. Soc.	*Trans.*	VI.	201–203	1896
„ „	The Norfolk and Norwich Microscopical Society, 1852–1884	„ „	„	„	214–223	„
Newton, Prof. A.	Early Notice of Spoonbill Breeding in Norfolk	„ „	„	„	158–159	„
Newton, John	The Mystery of Life	Liv'pool Lit. Phil. Soc.	*Proc.*	I.	341–357	„
Norton, Dr. J. A.	Facts and Fancies from the Note-book of a City Naturalist	Bristol Nat. Soc.	„	VIII.	48–54	„
Okell, R.	The Aims and Objects of the Microscopical Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	102–106	„
Oldham, C.	Recent Works on Land and Freshwater Shells	Yorks. Nat. Union	*The Naturalist*	For 1897	141–143	1897
Palmer, J. E.	The Migration of Birds	Dublin N. F. C.	*Irish Naturalist*	VI.	10–21	„
Paterson, John	Waste Ground and Suburban Bird-life: a Glasgow Study	Andersonian Nat. Soc.	*Annals.*	II.	46–49	1896
Patterson, A.	Fish Notes from Yarmouth	Norf. Norw. Nat. Soc.	*Trans.*	VI.	225–227	„
Patterson, R. L.	The Migration of Birds (Presidential Address)	Belfast N. H. Phil. Soc.	*Report and Proc.*	1895–96	17–19	„
Playne, H C.	Summer Visitors to the Neighbourhood of Bristol	Bristol Nat. Soc.	*Proc.*	VIII.	6–16	„
Plowright, C. T. M.	Black-winged Stilt	Norf. Norw. Nat. Soc.	*Trans.*	VI.	228	„
„ „	Fulmar Petrel	„ „	„	„	„	„
Porritt, G. T.	Preliminary List of the Neuroptera and Trichoptera of Yorkshire (omitting Psocidæ and Ephemeridæ)	Yorks. Nat. Union	*The Naturalist*	For 1897	115–126	1897
Potter, E. G.	The Roseate Tern still a British-breeding Bird	„ „	„ „	„	110	„
Richardson, N. M.	A List of Portland Lepidoptera, with Notes	Dorset N. H. A. F. C.	*Proc.*	XXVII.	146–191	1896

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Richardson, N. M.	Report on Observations of the First Appearances of Birds, Insects, &c., and the First Flowering of Plants in Dorset during 1895	Dorset N. H. A. F. C.	*Proc.*	XXVII.	197–209	1896
Robertson, Dr. D.	Nest-like Structures of *Lima hians*, Gmel.	Glasgow N. H. Soc.	*Journal*	IV.	331–332	1897
" "	Colouration of *Cancer pagurus*, Linn.	" "	"	"	332–333	"
" "	Habits of *Amphidotus cordatus*, Penn.	" "	"	"	333–334	"
Roebuck, W. D.	Bibliography: Birds, 1892	Yorks. Nat. Union	*The Naturalist*	For 1896	161–171	1896
" "	" Lepidoptera, 1892	" "	" "	"	211–232	"
" "	" Hemiptera, 1889 to 1893	" "	" "	"	305–308	"
" "	" Land and Freshwater Mollusca, 1890 and 1891	" "	" "	For 1897	27–40	1897
" "	" Hymenoptera, 1890 to 1892	" "	" "	"	159–166	"
Roechling, H. A.	Bacteria and their Importance in the Household of Nature	Leicester Lit. Phil. Soc.	*Trans.*	IV.	153–169	1896
" "	Life in Sewers	" "	"	"	312–329	1897
Russell, C. B.	The Protection of Wild Birds in Essex—The Shore Birds	Essex F. C.	*Essex Naturalist*	IX.	218–222	1896
Scharff, Dr. R. F.	*Canis vulpes melanogaster*, Bonap., in Ireland	Dublin N. F. C.	*Irish Naturalist*	V.	178	"
" "	A List of Irish Ostracoda, compiled from Brady & Norman's Catalogue	" "	" "	VI.	74–76	1897
Shrubsole, W. H.	Curious Dwellers on our Shores	Brighton N. H. Phil. Soc.	*Report*	1895–96	22–27	1896
Smith, W. A.	The Colouration of Fishes	Glasgow N. H. Soc.	*Journal*	IV.	335–343	1897
Southwell, Thos.	Some Additions to the Norwich Castle Museum in 1895	Norf. Norw. Nat. Soc.	*Trans.*	VI.	197–200	1896
" "	The Wild Birds Protection Acts of 1880 and 1894, as applied to the County of Norfolk	" "	"	"	207–214	"
Stanley, S. S.	Biographical Sketch of the Founder of the Warwickshire Field Club, the Rev. P. B. Brodie	Warw. N. A. F. C.	*Proc.*	41	i-iii	1897
Stephenson, Thos.	Couch's Whiting at Whitby: an addition to the Yorkshire Fauna	Yorks. Nat. Union	*The Naturalist*	For 1896	173	1896
" "	Natural History Notes from Whitby, May 1894 to May 1896	" "	" "	"	233–239	"
Swainson, E. A.	The Ornithology of the Brecon Beacons	Woolhope N. F. C.	*Trans.*	1893–94	153	"
" "	On the Distribution and Habits of the Pied Flycatcher in Wales	" "	"	"	154–157	"

	Isles		The Naturalist	For 1897	75–76	1897
Thomson, Jas. S.	Pearl-fishing in the South-west of Scotland	Dum. Gal. N. H. A. Soc.	*Trans.*	12	99–107	„
Tomalin, W.	Ornithological Notes, 1895	N'ton N. H. Soc.	*Journal*	IX.	25	1896
Tuck, W. H.	Aculeate Hymenoptera, &c., at Tostock, near Bury St. Edmunds	Norf. Norw. Nat. Soc.	*Trans.*	VI.	227–228	„
Vincent, Swale	The Suprarenal Capsules in the Lower Vertebrates	Birm. N. H. Phil. Soc.	*Proc.*	X.	1–26	„
Waterworth, H.	Birds of the Luddenden Valley	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	7–9, 57–20	„
Watkins, Rev. M. G.	Grayling in the Monnow	Woolhope N. F. C.	*Trans.*	1893–94	201–205	„
Watkins, Watkin	The Wild Cat: Notes on Specimens from the Caledonian Forest	Car. & Sev. Vall. F. C.	„	I.	160, 161	1897
Webb, W. M.	The Non-marine Mollusca of Essex	Essex F. C.	*Essex Naturalist*	X.	27–48	„
Whitlock, F. B.	Bird Notes from the Mid-Trent Valley	Yorks. Nat. Union	*The Naturalist*	For 1897	53–57	„
Wilkins, T. S.	The Microscope at the Seaside	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	71–78	1896
Wood, Rev. F. H.	The Cocoon of the Puss Moth (*Dicranura vinula*)	N'ton N. H. Soc.	*Journal*	IX.	70–72	„
„ „	Water Larvæ and the Changes	„ „	„	„	100–108	„
Wright, Albert E.	The Moths of Widdop	Halifax S. S. G. F. C.	*Halifax Naturalist*	II.	12–14	1897
Wright, C. E.	*Helix pomatia* (Linn.) not extinct in Northamptonshire	N'ton N. H. Soc.	*Journal*	IX.	61	1896

Section E.—GEOGRAPHY.

Atteridge, E. H.	Towards Khartoum (Lecture)	Tyneside Geog. Soc.	*Journal*	III.	408, 409	1897
Black, Surg.-Maj. W. J.	Cape Rivers and Harbours. (Extracts from a letter written in 1854)	Manch. Geog. Soc.	„	XII.	203, 204	„
Bolton, Herbe	The Physical Geography of North-east Lancashire	„ „	„	„	188–197	„
Bowes, Ald. I.	The Suez Canal	„ „	„	„	137–148	„
„ „	Proposed Nicaragua Canal	„ „	„	„	149–156	„
Brice, A. M.	Recent Polar Exploration (Lecture)	Tyneside Geog. Soc.	„	III.	275–278	1896
Crook, H. T.	On the Sale of Ordnance Survey Maps	Manch. Geog. Soc.	„	XI.	217–231	„
Curtis, William E.	Venezuela: Her Government, People, and Boundary. (Published by the American National Geographical Society)	Tyneside Geog. Soc.	„	III.	300–310	„
Fletcher, W. A. L.	A Journey towards Llassa	Liverpool Geog. Soc.	*Trans. and Report*	V.	74–92	1897
French-Sheldon, Mrs.	England's Commercial and Industrial Future in Central Africa (Lecture)	Tyneside Geog. Soc.	*Journal*	III.	415–418	„

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Goldsmid, Sir F. J.	Persia and her Neighbours: Part II.	Tyneside Geog. Soc.	*Journal*	III.	311–320	1896
Hanlon, Bishop	Uganda	Manch. Geog. Soc.	"	XII.	79–81	1897
Harper, W.	The Growth and Progress of the Australian Colonies	" "	"	"	109–127	"
Hewlett, E. G.	The Position of Geography as a School Subject	" "	"	XI.	255–263	1896
Hill, Gray.	A Journey to Petra, 1896	Liv'pool Geog. Soc.	*Trans. and Report*	V.	53–74	1897
Jackson, J. H.	The Niger River and Territories	Manch. Geog. Soc.	*Journal*	XII.	55–59	"
Kingsley, Miss M. H.	The Ascent of Cameroons Peak, and Travels in French Congo	Liv'pool Geog. Soc.	*Trans. and Report*	V.	36–52	"
"	Experiences in West Central Africa (Lecture)	Tyneside Geog. Soc.	*Journal*	III.	405–406	"
Leech, W. B.	Bonthe (Sierra Leone)	Manch. Geog. Soc.	"	XII.	31–36	"
Louis, Prof. H.	Malaysia and the Malays	Tyneside Geog. Soc.	"	III.	411–412	"
Maxwell, Sir W.	The Results of the Ashanti Expedition, 1895–96	Manch. Geog. Soc.	"	XII.	37–54	"
Mohn, Prof. H.	Dr. Nansen's North Polar Expedition, and its Scientific Results. (From the Christiania 'Morgenbladet.')	Tyneside Geog. Soc.	"	III.	279–283	1896
Nansen, Dr. F.	Some Results of the Norwegian Arctic Expedition. (Published by the Royal Geographical Society.)	" "	"	"	378–391	1897
Norman, Gen. Sir H. W.	Queensland	Manch. Geog. Soc.	"	XII.	82–108	"
Philip, Geo., jun.	The Enlargement of the Geographical Horizon, as illustrated in the History of Cartography down to the end of the Age of Discovery	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	313–339	1896
Pinnock, Jas., and T. B. Auchterlonie, jun.	Personal Experiences in Benin	Tyneside Geog Soc.	*Journal*	III.	392–403	1897
Reed, J. Howard	The Elements of Map Projection	Manch. Geog. Soc.	"	XI.	232–247	1896
" "	Practical Geography in Manchester	" "	"	XII.	183–187	1897
Robinson, Rev. W.	The Work of the Hausa Association	" "	"	"	60–64	"
Smith, Sir Donald A.	The Resources of Canada. (Lecture)	Tyneside Geog. Soc.	"	III.	285–299	1896
Smith, Rev. F. C.	Uganda	Manch. Geog. Soc.	"	XII.	65–73	1897
Thomson, J. P.	On Sir W. MacGregor's Journey in New Guinea	" "	"	"	201–203	"
Vivian, Rev. Wm.	The Mendi Country (Sierra Leone)	" "	"	"	1–34	"
Waller, W. C.	An Episode in the History of the River Lea	Essex F. C.	*Essex Naturalist*	IX.	190–191	1896
Wallis, W C.	Notes on a Journey from Tangier to Fez	Brighton N. H. Phil. Soc.	*Report*	1895–96	21–22	"
Wells, Lionel E.	The Canals and Navigable Rivers of England	Manch. Geog. Soc.	*Journal*	XII.	157–167	1897
Wilson, John	Visit to Lake Titicaca, Peru	Glasgow Phil. Soc.	*Proc.*	XXVII.	147–150	1896

Section F.—Economic Science and Statistics.

Barrett, Miss R. M.	Further Details as regards Foreign, Colonial, and American Legislation on Behalf of Destitute and Neglected Children	Stat. Soc. Ireland	*Journal*	X.	143–215	1896
Chisholm, Samuel	The History and the Results of the Operations of the Glasgow City Improvement Trust	Glasgow Phil. Soc.	*Proc.*	XXVII.	39–56	,,
Dawson, Charles	The Want of Industrial and Practical Education in Irish National Schools	Stat. Soc. Ireland	*Journal*	X.	216–217	,,
Dodd, W. H.	Introductory Address (Further Remarks on the Work of the Society)	,, ,,	,,	,,	125–128	,,
Hope, Dr. E. W.	Evolution of Sanitation—Liverpool, 1844–1894	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	293–312	,,
Hoskold, H. D.	Notes upon Foreign Mining Laws and Adequate Areas for Mining Concessions	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	160–173	1897
Irwin, Miss M. H.	Women's Industries in Scotland	Glasgow Phil. Soc.	*Proc.*	XXVII.	70–91	1896
Lodge, Prof. R.	Why has England become a Great Manufacturing, Commercial, and Colonising Country?	,, ,,	,,	,,	57–69	,,
Mitchell, G. A.	Presidential Address	Fed. Inst. Min. Eng.	*Trans.*	XI.	249–263	,,
Norman, A. R.	Natural Laws of Health and Modern Legislation (Presidential Address)	Rochester N. C.	*Roch. Naturalist*	II.	373–383	,,
Oldham, C. H.	The Fluctuating Character of Modern Employment	Stat. Soc. Ireland	*Journal*	X.	128–135	,,
Samuels, A. W.	A Suggestion for the Removal of Taxes on Litigation in Ireland as a Condition of the Reduction of the Judicial Establishment	,, ,,	,,	,,	135–143	,,
Stacy-Watson, C.	Notes on the Herring Fishery of 1895	Norf. Norw. Nat. Soc.	*Trans.*	VI.	147–153	,,
Williamson, R. S.	Presidential Address	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	XII.	79–84	,,

Section G.—Mechanical Science.

Bailey, Ernest J.	Saving Life in Colliery Explosions	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	XIII.	132–138	1897
Bell, W. R., and E. McGowan	Haulage at Wearmouth Colliery	N. Eng. Inst.	,, ,,	XI.	221–226	1896
Bramwell, Hugh	The Compound Winding Engine at the Great Western Colliery Company's Tymawr Pit: with Notes on its Comparative Steam Economy	Fed. Inst. Min. Eng.	,, ,,	XII.	282–288	1897
Bromly, A. H.	Notes upon Gold-mining in Burma	N. Eng. Inst.	,, ,,	,,	506–513	,,
Brown, Horace T.	Mechanical Roasting of Ores	Fed. Inst. Min. Eng.	,, ,,	XI.	369–377	1896
Brown, John	Automobiles, or Horseless Carriages (Lecture)	Belfast N. H. Phil. Soc.	*Report and Proc.*	1895–96	41–50	,,
,, ,,	Eccentric Haulage Clip	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	147	1897
Carrington, W.	Description of various Types of Ropeways, and Remarks as to their proper Selection	Fed. Inst. Min. Eng.	,,	,,	91–102	,,

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Chalmers, James	The late Mr. W. P. Buchan, Sanitary Engineer, Glasgow	Glasgow Phil. Soc.	*Proc.*	XXVII.	151–155	1896
Chaplin, G. P.	Cornish Methods of Mine Timbering	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	200–210	1897
Charleton, A. G.	The Indian Goldfields	Fed. Inst. Min. Eng.	,, ,,	XI.	345–368	1896
Clarke, T B. A.	Electric Coal-cutting on Longwall-faces	Midland Inst. Eng.	,, ,,	,,	492–501	,,
Cooper, F. E.	Sewerage Works and their Appliances	Liv'pool E. Soc.	*Trans.*	XVII.	93–105	,,
Donkin, Bryan	Powdered Coal for Firing Steam Boilers: Wegener and other Systems	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XI.	321–332	,,
Durnford, H. St. J., and Roslyn Holiday	The Use of Electricity at Ackton Hall Colliery	Mid. Inst. Eng.	,, ,,	XIII.	232–239	1897
Edwards, Clement	Railways and their relation to the Coal Trade	Fed. Inst. Min. Eng.	,, ,,	,,	107–117	,,
Flannery, F.	Refrigerating Machinery on Board Ship, with Notes on some recent Casualties	Liv'pool E. Soc.	*Trans.*	XVII.	175–186	1896
Fothergill, J. R.	Combustion in Marine Boilers	,, ,,	,,	,,	70–81	,,
Fowler, George	How a Mine may be Dry but not Dusty	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	XI.	128–135	,,
Galloway, W.	Secondary Haulage	Fed. Inst. Min. Eng.	,, ,,	XII.	257–262	1897
,, ,,	The Principal Pumping Engine at Llanbradach Colliery	,, ,,	,, ,,	,,	294–299	,,
,, ,,	Appliances for Winding Water	,, ,,	,, ,,	XIII.	74–84	,,
Gobert, A.	The Gobert Freezing Process of Shaft Sinking	,, ,,	,, ,,	XI.	297–304	1896
Hastie, James	Sinking, Surface-fittings, and Coal-cleaning Plant at Whistleberry Colliery, Hamilton	Mining Inst. Scot.	*Trans.*	XVIII.	56–63	1897
Head, Jeremiah	The Coal Industry of the South-Eastern States of North America	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	177–190	,,
Heleshaw, Prof. H. S.	Silting	Liv'pool E. Soc.	*Trans.*	XVII.	224–225	1896
Holiday, Roslyn	The Application of Electricity to Mining Operations	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XII.	2–12	,,
Hollis, H. W.	A Spring Coupling for Winding or Hauling Ropes	N. Eng. Inst.	,, ,,	,,	182–184	,,
Home, William	Lifting a Vertical Rising Main by Expansion	Chesterf. Mid. Count. Inst.	,, ,,	,,	105–106	,,
Howells, D. J.	Steam and Hydraulic Steering Gears	Liv'pool E. Soc.	*Trans.*	XVII.	201–213	,,
Lichtenberger, Th.	Honigmann System of Boring and Sinking Shafts	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	155–159	1897
McLaren, John	Road Locomotives	Fed. Inst. Min. Eng.	,, ,,	XI.	279–291	1896
Maginnis, A. J.	Inaugural Address	Liv'pool E. Soc.	*Trans.*	XVII.	1–19	,,

Maltby, Henry E.	The Enlargement of a Shaft at Lidgett Colliery without Interruption of Coal-winding	Mid. Inst. Eng.	*Trans. Fed. Inst.*	XII.	642–644	1897
Musker, Arthur	Artificial Paving Slabs	Liv'pool E. Soc.	*Trans.*	XVII.	31–39	1896
Noble, Algernon, and Norman Nisbet	Notes on Coal-mining	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	141–146	1897
Parkin, John H.	Notes on some Failures in Sewer Pipes	Liv'pool E. Soc.	*Trans.*	XVII.	49–60	1896
Piggford, John	Electric Haulage at Pleasley Colliery	Mid. Inst. Eng.	*Trans. Fed. Inst.*	XII.	633–638	1897
Piggford, Jonathan	Electric Haulage at Pleasley Colliery	Chesterf. Mid. Count. Inst.	" "	"	633–638	"
Ravenshaw, H. W.	Precautions necessary in the Use of Electricity in Coal Mines	Fed. Inst. Min. Eng.	" "	XI.	306–315	1896
Ross, Alexander	Light Railways: Conditions affecting their Construction and Working	Liv'pool E. Soc.	*Trans.*	XVII.	128–143	"
Scott, W. G.	Description of a Locomotive Depôt for the Accommodation of 180 Engines and Tenders	" "	"	"	21–24	"
Shaw, Saville	The Education of Metallurgists	N. Eng. Inst.	*Trans. Fed. Inst.*	XII.	488–494	1897
Simpson, H.	Description of Simpson's Brake for Steam Ships	Liv'pool E. Soc.	*Trans.*	XVII.	220–221	1896
Simpson, F. R.	Notes on the Sinking of Two Shafts at Claravale Colliery, near Wylam-upon-Tyne	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	193–199	1897
Smith, C. Sebastian	Safety-props for Supporting Cages in the Head-gear of Pits in cases of Overwinding	Chesterf. Mid. Count. Inst.	" "	XII.	564–566	"
Trestrail, N.	The Duty of Cornish Pumping Engines, Past and Present, and as compared with others	S. Staff. Inst. Eng.	" "	"	548–561	"
Walker, G. Blake	The Education of Mining Engineers (Presidential Address)	Midland Inst. Eng.	" "	"	135–159	1896
Watson, Simeon	Pit-top Safety Fencing	Chesterf. Mid. Count. Inst.	" "	"	122–123	"
Wight, W. D.	Anthracite Coal-breaking and Sizing Plant at Glyncastle Colliery	Fed. Inst. Min. Eng.	" "	"	238–245	1897
" "	Automatic Variable Expansion Gear applied to Balanced Slide-valve Winding Engines	" "	" "	"	298–281	"
Yates, John	The MacArthur-Yates Process of Gold Extraction: Dry Crushing with Direct Amalgamation and Cyanidation	" "	" "	"	361–365	"

Section H.—ANTHROPOLOGY.

Arnott, Samuel	Kirkbean Folklore	Dum. Gal. N. H. A. Soc.	*Trans.*	12	38–48	1897
Baker, Rev. Sir T. H. B.	Knowlton Church and Earthwork	Dorset N. H. A. F. C.	*Proc.*	XVII.	135–140	1896
Barbour, James	'A'Lorbune' inscribed on an Ancient Stone	Dum. Gal. N. H. A. Soc.	*Trans.*	12	96–99	1897

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Barbour, James	The Glenkens in the Olden Times	Dum. Gal. N. H. A. Soc.	*Trans.*	12	135–147	1897
" "	Recent Excavations at Birrens	" "	"	"	158–171	"
Brown, Horace T.	The Discovery of the Mummies of the Pharaohs	Burt. N. H. Arch. Soc.	"	III.	164–168	1896
Burne, Charlotte S.	What Folklore is, and how it is to be Collected	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	116–127	"
Cave, E. L.	Discovery of Foundations of an old Pigeon House at Instone, near Bromyard	Woolhope N. F. C.	*Trans.*	1893–94	264–266	"
Chalmers, Rev. A.	The Barony of Fetterangus	Buchan F. C.	"	IV.	33–67	1897
Chinnock, Dr. E. J.	A Prehistoric Chisel	Dum. Gal. N. H. A. Soc.	"	12	20–22	"
Coffey, George	From Egypt to Ireland. A Chapter in the History of Ornament (Lecture)	Belfast N. H. Phil. Soc.	*Report and Proc.*	1895–96	20–23	1896
Coles, Fred. R.	On some of the Place Names of the Stewartry	Dum. Gal. N. H. A. Soc.	*Trans.*	12	56–66	1897
Collyer, H. C.	The Contents of some Tumuli on the South Downs	Croydon M. N. H. C.	"	1895–96	179–184	1896
Crellin, Miss A. M.	Report of Anthropological Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	119–120	"
Cunnington, E.	Flint Implements found at Portesham during 1894 and 1895	Dorset N. H. A. F. C.	*Proc.*	XVII.	192–193	"
Dale, W.	The Palæolithic Implements of the Southampton Gravels	Hants F. C.	"	III.	261–264	1897
"	Ancient Bronze Weapons from the Neighbourhood of Southampton	"	"	"	265–266	"
Davies, James	Caerleon-upon-Usk (Isca Silurum) and Caerwent (Venta Silurum)	Woolhope N. F. C.	*Trans.*	1893–94	245–251	1896
Elworthy, F. T.	An Ancient British Interment	Som'setsh. A. N. H. Soc.	*Proc.*	XLII. Pt. II.	56–66	"
Galpin, Rev. F.	China's Tribute to the Dead. (The large amount of Land devoted to Burial purposes.)	Manch. Geog. Soc.	*Journal*	XI.	209–216	"
Given, Dr. J. C. M.	Modern Aspects of Heredity	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	101–124	"
Hancock, Rev. F.	Two Barrows on the Brendon Hills	Som'setsh. A. N. H. Soc.	"	XLII. Pt. II.	22–25	"
Hopton, Rev. M.	Inscribed Stone found in Munsley Church	Woolhope N. F. C.	*Trans.*	1893–94	178–179	"
Kermode, P. M. C.	Report of the Archæological Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	116–119	"
Law, Robert	Evidences of Prehistoric Man on the Moorlands in and around the Parish of Halifax	Halifax S. S. G. F. C.	*Halifax Naturalist*	II.	{1–6, 29–31}	1897
Lynam, C.	Sectional Report—Archæology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	101–107	1896
Macdonald, Dr. J.	The Inscribed Roman Stones of Dumfriesshire	Dum. Gal. N. H. A. Soc.	*Trans.*	12	108–130	1897
Mansel-Pleydell, J. C.	On a Romano-British Brick-kiln and a British Barrow at Bagber, Milton Abbas, with an Historical Dissertation on Pottery and Brick-making	Dorset N. H. A. F. C.	*Proc.*	XVII.	127–134	1896

Middleton, Dr. J.	Studies in Anthropology (Address)	Buchan F. C.	*Trans.*	IV.	5–16	„
Milligan, S. F.	Antiquities, Social Customs, and Folklore of Tory, Innismurray, and the South Islands of Aran (Lecture)	Belfast N. H. Phil. Soc.	*Report and Proc.*	1895-96	27–36	1896
Moore, H. Cecil	The supposed Roman Bridge in the Grounds of the New Weir, Kenchester	Woolhope N. F. C.	*Trans.*	1893–94	56–60	„
„ „	Remarks on Flint Flakes found by Mr. Edy Ballard near Ledbury	„ „	„	„	191–193	„
Moxon, R.	Croxden Abbey	Burt. N. H. Arch. Soc.	„	III.	131–136	„
Nevins, J. Ernest	Hindu Domestic and Religious Customs	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	263–291	„
Odling, W.	The Roman Catacombs	Burt. N. H. Arch. Soc.	*Trans.*	III.	118–120	„
Parkes, J. C. E.	The 'Man-eating' People of the Imperri	Liv'pool Geog. Soc.	*Trans. and Report*	V.	92–93	1897
Payne, George	Archæology, with especial reference to Kentish Antiquities (Abstract of four Lectures)	Rochester N. C.	*Roch. Naturalist*	II.	421–434	„
Pettifourt, E. J.	The Foundations of Scientific Progress (Inaugural Address)	Brighton N. H. Phil. Soc.	*Report*	1895-96	5–8	1896
Phillips, William	Garmsley Camp	Woolhope N. F. C.	*Trans.*	1893-94	142–145	„
Prowse, Dr. A. B.	Some Ancient British Remains near Long Ashton, Somerset	Bristol Nat. Soc.	*Proc.*	VIII.	41–45	„
Quine, Rev. John	The Manx Doomsday Book	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	92–95	„
„ „	Treens (a Manx Land Division), with special Reference to Lonan for illustration	„ „ „	„ „	„	95–102	„
„ „	Retiring Presidential Address	„ „ „	„ „	„	113–115	„
Reid, Clement	An Early Neolithic Kitchen-Midden and Tufaceous Deposit at Blashenwell, near Corfe Castle	Dorset N. H. A. F. C.	*Proc.*	XVII.	67–75	„
Roeder, C.	Contributions to the Folklore of the Isle of Man	I. of Man. N. H. A. Soc.	*Yn Lioar Manninagh*	III.	129-191	1897
Sephton, Rev. J.	On some Runic Remains	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	183–209	1896
Shaw, James	Adder Beads and Children's Rhymes	Dum. Gal. N. H. A. Soc.	*Trans.*	12	48–56	1897
Shore, T. W.	Traces of the Language of the Prehistoric and other Ancient Races contained in the Place Names of the County	Hants F. C.	*Proc.*	III.	233–256	„
Southam, S. C.	Some Myths and Fancies of Animal Life (Lecture)	Car. and Sev. Vall. F. C.	*Trans.*	I.	154–160	„
Spence, James	Dunnottar Castle	Buchan F. C.	„	IV.	22–25	„
Taylor, W. L.	Scottish Ballads (Lecture)	„	„	„	19–21	„
Thomson, Rev. J. H.	On some Camps or Forts in the Parishes of Dryfe and Lochmaben	Dum. Gal. N. H. A. Soc.	„	12	28–31	„
Tucker, W. Trueman	On some supposed British Remains from Rothley, Leicestershire	Leicester Lit. Phil. Soc.	„	IV.	212–218	1896
Waldron, Clement	Llandaff Cathedral Precincts	Cardiff Nat. Soc.	„	XXVIII.	16–23	„

Section I.—Physiology.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Barrowman, Jas.	The Health Conditions of Coal-mining	Mining Inst. Scot.	*Trans.*	XVII.	98–106	1896
Coats, Prof. J.	Immunity to Infective Diseases: a Pathological Study in view of Recent Researches	Glasgow Phil. Soc.	*Proc.*	XXVII.	20–38	"
Haldane, Dr. J. S.	The Causes of Death in Colliery Explosions	Mining Inst. Scot.	*Trans.*	XVIII.	20–31	"

Section K.—Botany.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Audley, J. A.	Sectional Report—Botany	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	65–70	1896
Baker, Edmund G.	On a new Dorsetshire Variety of *Plantago coronopus*, Linn.	Dorset N. H. A. F. C.	*Proc.*	XVII.	87–95	"
Barnes, R.	Some new Records for the Moss Flora of Nidderdale and Wensleydale; with additional Localities for North Yorkshire and South Durham	Yorks. Nat. Union	*The Naturalist*	For 1897	179–188	1897
Baylis, Philip	The Growth of Oaks: Seed *versus* Transplantation	Woolhope N. F. C.	*Trans.*	1893–94	138–141	1896
Bennett, Arthur	*Carex aquatilis*, Wahlb., in Lancashire	Yorks. Nat. Union	*The Naturalist*	For 1897	77–80	1897
Botanical Section	Annual Report	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	96–98	"
Boulger, Prof. G. S.	Our Forest Trees, and how they should be represented in the Forest Museum at Chingford	Essex F. C.	*Essex Naturalist*	IX.	243–244	"
Boyd, John	The Pollok Wych Elms (*Ulmus montana*)	Andersonian Nat Soc.	*Annals*	II.	5–7	1896
Braithwaite, Dr. R.	The Study of Mosses (Presidential Address, 1895)	Yorks. Nat. Union	*Trans.*	20	6–16	"
Buxton, E. N.	Observations on the Management of the Woodland in Epping Forest	Essex F. C.	*Essex Naturalist*	IX.	233–236	1897
Cocks, Ll. J.	Some Nidderdale Mosses	Yorks. Nat. Union	*The Naturalist*	For 1897	189–190	"
Colgan, N.	*Scrophularia umbrosa* (Dum.) in Ireland	Dublin N. F. C.	*Irish Naturalist*	V.	182	1896
" "	On the Flora of the Ox Mountains, Co. Sligo	" "	" "	"	301–308	"
" "	*Euphrasia Salisburgensis*, Funk. in Ireland	" "	" "	VI.	105–108	1897
Cooke, J. N.	Algæ found at Roche Abbey on July 11, 1896	Yorks. Nat. Union	*The Naturalist*	For 1896	321–323	1896

Cooke, Dr. M. C.	The Essex Fungi, and how they should be represented in the Forest Museum at Chingford	Essex F. C.	*Essex Naturalist*	X.	1–8	1897
Corrie, John	Annotated List of Rarer Plants met with in North-west Dumfriesshire	Dum. Gal. N. H. A. Soc.	*Trans.*	12	148–154	"
Coy, F.	*Chelidonium majus*	N'ton N. H. Soc.	*Journal*	IX.	55	1896
Crossland, C.	Fasciation	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	33	"
" "	The Fly Agaric (*Amanita muscaria*)	" "	" "	"	67–69	"
" "	Fungus Foray at Selby, with List of Species found	Yorks. Nat. Union	*The Naturalist*	For 1896	355–365	"
Crump, W. B.	The Flora of the Parish of Halifax	Halifax S. S. G. F. C.	*Halifax Naturalist*	App.	1–32	1896, 1897
Darton, Hugh	Mosses collected in the Neighbourhood of Hertford	Herts N. H. Soc.	*Trans.*	IX.	104–108	1896
Dixon, H. N.	Phenological Observations, 1895	N'ton N. H. Soc.	*Journal*	IX.	81–83	"
Feilden, Col. H. W., & H. D. Geldart	A Contribution to the Flora of Russian Lapland	Norf. Norw. Nat. Soc.	*Trans.*	VI.	161–167	"
" "	A Contribution to the Flora of Kolguev	" "	"	"	168–184	"
Fowler, Rev. W.	Mosses of South Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1896	241–243	"
Gibson, Rev. T. B.	The Botany of a School Playground in the Heart of Dublin	Dublin N. F. C.	*Irish Naturalist*	V.	277–284	"
Gray, Peter	Food Plants (Lichens, Fungi, Algæ)	Dum. Gal. N. H. A. Soc.	*Trans.*	12	66–69	1897
Harris, G. H.	Flora of Great Yarmouth District	Norf. Norw. Nat. Soc.	"	VI.	137–147	1896
Heathcote, Rev. E. D.	Note on the Moss *Eurhynchium tenellum*, Milde, previously recorded as *Rhyncostegium curvisetum*, Brid.	Hants F. C.	*Proc.*	III.	280–281	1897
Henry, John	New Plant Records for Lake Lancashire	Yorks. Nat. Union	*The Naturalist*	For 1897	127	"
Hepworth, John	Flora of Our Ten-mile Radius	Rochester N. C.	*Roch. Naturalist*	II.	383–387 389–401 417–420	1896 " 1897
Hodgson, William	*Vicia lutea* and other Rare Plants near Workington, Cumberland	Yorks. Nat. Union	*The Naturalist*	For 1897	145–147	"
Holmes, W. Murton	The Fertilisation of Flowering Plants: some Methods of Pollination	Croydon M. N. H. C.	*Trans.*	1895–96	186–194	1896
Johnson, Prof. T., & Miss E. Hensman	Algæ from the North side of Belfast Lough	Dublin N. F. C.	*Irish Naturalist*	V.	252–253	"
Johnson, Prof. T., and Miss M. C. Knowles	Seaweeds from the South-east of Ireland	" "	" "	VI.	139–140	1897
Keegan, Dr. P. Q.	The Chemistry of some Common Plants	Yorks. Nat. Union	*The Naturalist*	For 1897	41–47	"
Kermode, Rev. S. A. P.	Report of the Botanical Section	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	121–122	1896

Section K.—BOTANY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Law, Wilby	Phenological Observations, 1896, taken near Northampton	N'ton N. H. Soc.	*Journal*	IX.	83	1896
" "	Kingsthorpe Bush Close	" "	"	"	84–85	"
Lee, John R.	Plants of the Kenmuir District of the Clyde	Andersonian Nat. Soc.	*Annals*	II.	8–15	"
Lees, F. Arnold	In Memoriam: Thomas Hick, B.A., B.Sc., A.L.S.	Yorks. Nat. Union	*The Naturalist*	For 1897	81–84	1897
" "	" Henry Boswell	" "	" "	"	132	"
Ley, Rev. Augustin	Two New British Rubi	Woolhope N. F. C.	*Trans.*	1893–94	233 235	1896
" "	Three New Bramble Forms	" "	"	"	236–237	"
" "	Additions to the Flora of Herefordshire	" "	"	"	1–89 (App.)	"
Lister, Arthur	Practical Hints on the Study of the Mycetozoa, with Notes on the Epping Forest Species	Essex F. C.	*Essex Naturalist*	X.	23–27	1897
Lowe, Dr. John	Diatoms of Sleaford District, 1856	Yorks. Nat. Union	*The Naturalist*	For 1896	304	1896
McAndrew, James	Botanical Notes for 1895	Dum. Gal. N. H. A. Soc.	*Trans.*	12	22–23	1897
" "	Botanical Notes for 1895—Wigtownshire	Glasgow N. H. Soc.	*Journal*	IV.	344–346	"
M'Ardle, David	Hepaticæ collected in Co. Carlow	Dublin N. F. C.	*Irish Naturalist*	V.	200–202	1896
M'Weeney, Dr. E. J., and R. Ll. Praeger	Notes on the Fauna and Flora of Clonbrock, Co. Galway	" "	" "	"	217–221	"
Mason, P. B., and others	The Flora of Burton-on-Trent and Neighbourhood (Part I.)	Burt. N. H. Arch. Soc.	*Trans.*	III.	177–190	"
Massel, George	Parasitic Fungi: their Mode of Attack and the Means of its Prevention (Abstract of Lecture)	Herts N. H. Soc.	"	IX.	14–18	"
Meyrick, E.	Observations on Plants near Marlborough	Marlb. Coll. N. H. Soc.	*Report*	45	64–74	1897
Moore, H. Cecil	Measurements of Fine Oak Trees in Herefordshire	Woolhope N. F. C.	*Trans.*	1893–94	128–130	1896
Morris, Dr. G. H.	Micro-organisms in Relation to Man (Presidential Address, 1893)	Burt. N. H. Arch. Soc.	"	III.	91–110	"
Moss, C. E.	Why do Flowers Bloom in Spring and Autumn?	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	61–63	"
Mott, F. T.	Some Popular Names of British Plants	Leicester Lit. Phil. Soc.	*Trans.*	IV.	209–211	"
Moule, H.	Notes on Two Instances of Tenacity of Vegetable Life	Dorset N. H. A. F. C.	*Proc.*	XVII.	123–126	"
Murray, James	Clydesdale Mosses	Andersonian Nat. Soc.	*Annals*	II.	16–21	"
Murray, Rev. R. P.	The Flora of Somerset: Last Instalment (For previous parts, see Proceedings, 1893–1895)	Som'setsh. A. N. H. Soc.	*Proc.*	XLII. Pt. II.	App.	"
[illegible]	The Position of Annual Flowering Plants	Yorks. Nat. Union	*The Naturalist*	For 1897	1–4	1897

Petty, Lister	The Constituents of the North Lancashire Flora, 1597 (?)–1893	" "	" "	" For 1897	341–348 85–92	" 1897
Praeger, R. Ll.	The Plants of Inismurray, Co. Sligo	Dublin N. F. C.	*Irish Naturalist*	V.	177–178	1896
" "	The Field Clubs in Cavan	" "	" "	"	193–199	"
" "	*Medicago silvestris* in Ireland	" "	" "	"	249–251	"
" "	The Island Flora of the Connemara Lakes	" "	" "	"	292–293	"
" "	Irish Plants, collected chiefly in the Province of Leinster in 1896	" "	" "	VI.	89–100	1897
Preston, Rev. T. A.	Insects in Relation to the Fertilisation of Flowers	Leicester Lit. Phil. Soc.	*Trans.*	IV.	177–191	1896
Pye, Miss Clara E.	My Collection of Swiss Flowers	Rochester N. C.	*Roch. Naturalist*	II.	405–411	1897
Roebuck, W. D.	Bibliography: Ferns, Fern-Allies, and Characeæ, 1888–89	Yorks. Nat. Union	*The Naturalist*	For 1897	95–100	"
Saunders, James	Notes on the Characeæ, with a List of Species from the South Midlands	Herts N. H. Soc.	*Trans.*	IX.	19–26	1896
Scott-Elliott, G. F.	The Work of the Future British Botanist	Dum. Gal. N. H. A. Soc.	"	12	7–15	1897
" "	Report on the Dumfries Herbarium	" "	"	"	132–135	"
Slater, M. B.	*Jubula Hutchinsiæ*: a Rare Hepatic, new to Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1897	128	"
Smith, B. M.	Yorkshire Naturalists at Hackfall and Tanfield	" "	" "	For 1896	189–196	1896
Smith, John	Records of Excursions in Ayrshire	Andersonian Nat. Soc.	*Annals*	II.	22–45	"
Soppitt, H. T.	Mosses in the Hebden Valley	Halifax S. S. G. F. C.	*Halifax Naturalist*	I.	91–93	1897
Stabler, George	On the Hepaticæ and Musci of Westmoreland	Yorks. Nat. Union	*The Naturalist*	For 1896 For 1897	277–284 5–12	1896 1897
Stewart, William	*Bolbitius bulbillosus*, Fr., a Fungus new to Britain	Glasgow N. H. Soc.	*Journal*	IV.	355–356	"
West, W. and G. S.	On the Collection of Freshwater Algæ	Yorks. Nat. Union	*The Naturalist*	For 1897	157–158	"
Whitwell, Wm.	Henry Boswell and West Yorkshire Mosses	" "	" "	"	173–176	"
Wilkinson, H. J.	Catalogue of British Plants in the Herbarium of the Yorkshire Philosophical Society (Part III.)	Yorks. Phil. Soc.	*Report*	For 1896	13–35	"
Woodruffe-Peacock, Rev. E Adrian	A Critical Catalogue of Lincolnshire Plants	Yorks. Nat. Union.	*The Naturalist*	For 1896 " " " For 1897 "	181–188 245–252 309–316 325–332 133–140 167–172	1896 " " " 1897 "
" "	Lincolnshire Naturalists at Bourne	" "	" "	For 1896	293–298	1896
" "	Lincolnshire Naturalists at Great Cotes	" "	" "	"	367–372	"
" "	Cow-grass and Rye-grass	" "	" "	For 1897	21–25	1897

Report on the State of the Principal Museums in Canada and Newfoundland. By Henry M. Ami, *M.A., D.Sc,, F.G.S., of the Geological Survey of Canada, Ottawa.*

[Ordered by the General Committee to be printed *in extenso.*]

The following report on the state of the principal museums in Canada and Newfoundland is based upon information contained in a correspondence between the Director of the Geological Survey Department at Ottawa (Dr. Dawson) and the curators or officers in charge of the several museums, who very kindly supplied the information desired.

The four following points in connection with museums received particular attention :—

1. The approximate number of specimens classified and displayed in each museum.
2. The relative importance of collections in geological, mineralogical, botanical, zoological, ethnological, or other classes of material.
3. Any special collections acquired from individuals included in the museum.
4. Types of species (if any) preserved in the museum, with the name of the describers.

The order in which the several museums are presented is *geographical.* Beginning with the most easterly one, the Museum of the Geological Survey of Newfoundland, St. John's, Newfoundland, and closing with the Provincial Museum of British Columbia, Victoria, British Columbia.

The principal object in view in preparing this report was to gather definite information regarding the amount of material at present housed in the various museums of the country, and thus enable the Director of the National Museum at Ottawa and others, to whom applications for information are constantly coming in, to give satisfactory replies.

The report consists of a consecutive list of museums in Canada and Newfoundland, including only the principal ones known to the Department, with brief descriptions or abstracts of the contents of the different museums enumerated.

Brief descriptions and notes on fifty-one private collections in Canada are also added.

This report does not profess to be complete in every respect. The information presented, however, has been obtained from the most reliable sources available—from official letters sent by the curators or officers in charge of the several museums addressed, or from published papers and reports on the contents of museums in the different provinces.

The thanks of the writer are due to Dr. G. M. Dawson, Director of the Geological Survey Department at Ottawa, for many valuable suggestions and kind offices in preparing this report.

Geological Survey of Newfoundland.—Contains about 3,000 specimens, of which 2,000 at least are arranged and classified, to illustrate the economic and natural resources of this colony. The mineralogical cabinets comprise 600 specimens; the palæontological and geological

collections include 850 specimens; whilst the collections of birds, fishes, shells, &c., number together 426 specimens. There is an herbarium of the plants of the island, prepared by Professors B. L. Robinson and H. Schenck, of Harvard. Economic exhibits of the fisheries (seal and fish-oil, &c.) of Newfoundland. There is also a fair collection of ethnological specimens, besides a numismatic collection. Museum, in charge of J. P. Howley, Esq., F.G.S., Director of the Geological Survey of Newfoundland, and supported by the legislative grant, is located in St. John's, Newfoundland, in the Post Office Building.

Provincial Museum, Halifax, Nova Scotia.—Contains about 10,000 specimens. The geological cabinets include: Minerals, 1,000 specimens; rocks, 300 specimens; fossil organic remains, 2,000 specimens, for the most part collected and arranged by the late Dr. D. Honeyman. The zoological department includes 1,500 specimens, and the botanical collection is that prepared by Dr. Henry How. Museum supported by grant from the Legislature of Nova Scotia, and in charge of Dr. E. Gilpin, F.G.S., Commissioner of Mines for the province. Located in a large room, 80 feet by 20 feet, in the uppermost storey of the Halifax City Post Office, the property of the Dominion Government. Types. Contains a few types of fossils described by Dr. Honeyman and the type specimen of a giant squid described by Professor A. E. Verrill. Curator: Dr. E. Gilpin, M.A., F.G.S., Halifax, Nova Scotia.

The University Museum, Dalhousie University, Halifax, Nova Scotia.—Contains upwards of 1,600 specimens, classified and arranged for the use of students and professors. Of 700 specimens in the zoological collection the native birds of Nova Scotia form an important part. The geological cabinets comprise a good series of Nova Scotian minerals, Nova Scotian carboniferous fossils, and European cretaceous fossils, 450 specimens in all. The Patterson collection of archæological remains from various parts of Nova Scotia and Prince Edward Island is of considerable importance: it includes 330 pieces. The Thomas McCulloch collections comprise birds, rocks, fossils, minerals, and plants. An herbarium illustrating the flora of Nova Scotia is in course of preparation. Supported by the University authorities and by the Thomas McCulloch fund of $1,400 given to Dalhousie in 1884. The Rev. Dr. Forrest, principal, and Professor E. Mackay, pro-curator, in charge, Halifax, Nova Scotia.

Acadia University Museum, Wolfville, Nova Scotia.—Contains upwards of 5,000 specimens, neatly arranged and classified for the use of students and professors. The geological cabinets include 504 specimens of minerals, 365 rock specimens, and 800 fossil organic remains. The zoological collections comprise 690 specimens, divided as follows:—*Ornithological*: birds, birds' eggs, and their nests, 300 specimens. *Conchological*, 300 species, besides a large number of marine invertebrates. In the herbarium we find nearly all the plants occurring in New Brunswick, presented by G. U. Hay, of St. John, N.B., besides collections from various parts of the province and from foreign countries. There is also a small ethnological collection. The zeolites, amethysts, and trap rocks from Blomidon are of local and special interest. There is also a fair collection of coins. Curator: Professor A. E. Coldwell, M.A., Wolfville, Nova Scotia.

King's College Museum, Windsor, Nova Scotia.—For the use of students. Contains 5,500 specimens. The mineralogical cabinets hold the first place; the botanical collections come next. The next important individual collection is the Cosswell Herbarium of phæno-

gamous and cryptogamous plants from Great Britain. Supported by the Senate of King's College. Acting Curator: Professor F. W. Vroom, Windsor, Nova Scotia.

Pictou Academy Museum, Pictou, Nova Scotia.—Includes a very good and fairly complete collection of the birds and mammals of the county of Pictou, an herbarium, and a cabinet of geology illustrating the minerals of Nova Scotia, with special reference to the coals, iron ores, and fossil remains of Pictou County. Enriched by numerous collections made and arranged by Dr. A. H. Mackay, Superintendent of Education for Nova Scotia, and a past principal of the Academy.

Natural History Society of New Brunswick Museum, St. John, N.B.—Contains about 15,000 specimens, arranged and classified. The Gesner Museum of Geology, &c., is included in the same building. Geological collections comprise 1,400 specimens of minerals, upwards of 1,000 specimens of fossils, and the zoological department, embracing collections of birds, fishes, reptiles, mammals, insects, shells, birds' eggs, and birds' nests, contains 3,741 specimens in all. There is a good herbarium, comprising about 6,500 sheets, 1,500 New Brunswick phanerogams and cryptogams, and 5,000 phanerogams, foreign, European, West Indies, United States, Canada. About 600 specimens in the archæological cabinets and 200 in the ethnological series. The palæontological collections are chiefly those of Dr. G. F. Matthew and of the late Professor C. F. Hartt.

Type specimens of fossil organic remains from rock formations in the vicinity of St. John, &c., described by Dr. Matthew, Professor S. H. Scudder, Mr. C. F. Hartt, and Sir J. W. Dawson are carefully preserved in the cabinets of this museum.

'The most valuable,' Dr. Matthew writes, 'are the types of the Devonian plants collected by Hartt and described by Sir William Dawson.[1] There are here also the types of the fossil insects described by Dr. S. H. Scudder that were collected by Hartt.' Also some few other types and a good many typical fossils of various formations. The museum is housed in six rooms on the second floor of St. John City Market, Charles Street. The society receives a small annual grant from the New Brunswick Legislature. Curators of the Museum: Dr. G. F. Matthew, Samuel W. Kain, Esq., A. Gordon Leavitt, Esq.

The University Museum, University of New Brunswick, Fredericton, N.B.—Organised about 1836 by Dr. James Robb. The approximate number of specimens classified and displayed to-day in the museum is 2,800, of which about 1,300 belong to the geological collections of minerals, rocks, and fossils from various parts of New Brunswick and other provinces of Canada, Europe, and the United States. There are 1,495 specimens in the zoological cabinets, including birds, birds' eggs (representing 250 species), reptiles, crustaceans, fishes, insects, molluscs, and star-fishes, &c., most of which are the gift of foreign institutions and societies. There is also the nucleus of a small archæological collection, including pipes, pottery, and stone implements from New Brunswick, with a few from the United States. The economic mollusca, the Cambrian fossils of St. John, New Brunswick, and the ornithological collection by Messrs. Ganong, Matthew, and Adney respectively comprise the most conspicuous and

[1] See *Reports on Fossil Plants of the Devonian and Upper Silurian of Canada.* Geological Survey of Canada, Montreal, 1871.

special collections. Curator: Professor L. W. Bailey, M.A., Ph.D., F.R.S.C., Professor of Geology, University of New Brunswick.

Muséum de l'Université Laval, Québec, Quebec.—The nucleus of this collection, which now amounts to 35,000 specimens, arranged and classified, was the old 'Cabinet de Minéralogie' of the Quebec Seminary. The mineralogical cabinet to-day comprises more than 4,000 specimens. Of special interest is a collection of minerals made by the Abbé Haüy for the Quebec Seminary. Besides 1,000 specimens of rocks, determined by Dr. Sterry Hunt, the geological collections include upwards of 1,000 fossil remains, some from Canada, determined by the late Mr. E. Billings and by Dr. H. M. Ami, others from the late Abbé Joachim Barrande, of Bohemia. The zoological collections include 17,000 specimens: 1,200 mammals, 14,000 insects, and 2,000 shells from various parts of the world. The botanical collections, including l'Abbé O. Brunet's herbarium, named by Gray, Hooker, Engelman, and Michaux, comprise upwards of 10,000 sheets. Herbaria, by Hall, Parry, Harbour, Geyer, N. Rield, Leidenberg, Vincent, Moser, Smith, Durand, Nuttall, and Rafinesque are also included in the botanical collection at Laval.

The dried specimens of plants are supplemented by an excellent collection of woods from Canada and foreign countries.

An archæological and ethnological collection of about 1,000 pieces, prepared by Dr. Joseph Charles Taché, for the most part illustrates the manners and customs of the Huron aborigines and Indians of North-East America. The numismatic collection contains some 3,000 coins and medals.

The 'Lea collection' of Unios, the Macoun collection of North-West Canadian plants, the St. Cyr Herbarium of Quebec, the Dr. Ahern collection of Quebec fossils, form some of the more conspicuous collections in the museum of the University. Curator and Rector: Very Rev. Mgr. J. C. K. Laflamme, P.A., F.R.S.C.

Muséum de l'Instruction Publique, Québec, Quebec.—Contains 32,450 specimens, neatly housed, but uncomfortably overcrowded in a portion of the uppermost storey of the Provincial Parliament Building, Quebec. The local Legislature has given a small annual grant to the curator for the support and maintenance of this museum for a number of years. The geological collections consist of 3,500 specimens of minerals and 780 fossils. The zoological collections amount to 4,430 specimens as follows: Mammals, 60; birds (mounted), 46; birds (skins), 514; birds' eggs, 271; fishes, 65; mollusca, 3,480. The entomological collection is large and contains 15,670 specimens, including as it does l'Abbé Provancher's type collections of Canadian insects, described and figured in his 'Faune Entomologique de Québec.' The St. Cyr Herbarium is very extensive, and includes an excellent series of the Quebec flora. It contains 7,870 sheets. Curator of the Museum: Mons. D. N. St. Cyr, Québec, Quebec.

Muséum du Séminaire de Philosophie, Montréal, Quebec.—For the use of the students and professors. Contains about 6,300 specimens, of which 2,000 are geological (minerals and rocks); 1,500 palæontological; 2,810 zoological, besides a fair collection of botanical specimens for teaching purposes. Amongst the special collections we note one, 'Collection de Minéralogie faite pour le Collège de Montréal par les soins du célèbre Haüy, 1822.' Most of the fossils are European. Curator: L. Lepoupon.

Muséum du Collège Saint-Laurent, St. Laurent, near Montreal, Quebec

Miscellaneous collections, comprising upwards of 18,000 specimens. Upwards of 1,000 specimens each of minerals, rocks, and fossils comprise the geological cabinets, and as many each of the zoological and botanical collections, according to the curator's report. The 'Crevier collection' of fossils from Montreal and vicinity and a numismatic collection form the most interesting special collections we note in this museum. Supported by private contributions and donations of friends to the Congregation of the Holy Cross. The collections are classed under twenty-five heads and in charge of the curator—Rev. Joseph C. Carrier, C.S.C., St. Laurent, Quebec.

Peter Redpath Museum of McGill College, Montreal, Quebec.—75,000 specimens, arranged and classified for the use of professors, students, and the general public in a large, well lighted, and commodious fire-proof building, built for the purpose, in 1882, by the munificent gift of the late Peter Redpath, Esq. The geological collections, including the Dawson collections of Devonian, Carboniferous, and Cretaceous fossil plants, of Pleistocene fossils, Microsauria, Eozoon, and many other types, and the Logan Memorial Collection include some 16,540 specimens, divided as follows:—Fossils, 8,000; minerals, 2,880; rock specimens, 5,660. The Holmes and Miller cabinets of minerals are included in the above figures. There are also excellent collections of petrographical slides. The zoological collections comprise 19,685 specimens as follows:—

	Specimens
Mammals	170
Birds	500
Birds' eggs	125
Reptiles	90
Fishes	200
Crustacea	300
Mollusca	7,500
Insects	10,000
Echinodermata	250
Annulata	100
Anthozoa	200
Protozoa and Hydrozoa	250

The University Herbarium consists of upwards of 30,000 sheets, and includes the Holmes Herbarium and the Macoun collections of Canadian plants, exhibited at the World's Centennial Exhibition, Philadelphia, in 1876. There are also representative collections from Australia, India, Japan, South Africa, South America, and Northern Europe. Specimens of the Canadian timber trees, as well as those of the United States and foreign countries, are included in the 'Economic Collection.' Botanical collections in charge of Professor D. P. Penhallow.

The archæological and ethnological collections comprise some 1,200 specimens illustrating the implements, pottery, and weapons of the aborigines of Canada and foreign countries, besides Egyptian antiquities in the Dawson collection.

The 'Carpenter collection' of shells is a special feature, and contains many types. The Chitonidæ are of special interest. The McCulloch collection of birds is also worthy of note, besides the entomological collections of Messrs. Bowles, Cooper, and Pearson, acquired for the museum in recent years.

Types.—This museum contains numerous type specimens of species and

varieties of recent and fossil organisms described by Sir William Dawson, Professor James Hall, George Jennings Hinde, T. Rupert Jones, Joseph Leidy, O. C. Marsh, D. P. Penhallow, J. T. Donald, and P. P. Carpenter. Hon. Curators: Sir William Dawson, Dr. B. J. Harrington, Dr. D. P. Penhallow, Dr. F. D. Adams, Dr. W. E. Deeks, Peter Redpath Museum, Montreal.

Museum of the Natural History Society of Montreal, Montreal, Quebec.—Total number of specimens displayed and classified, 18,250. Of these the zoological collections comprise nearly two-thirds, viz., 11,220 specimens, as follows:—

Mammals (mounted)	150
Birds (mounted)	1,300 [1]
Reptiles (mounted)	50
Fish (mounted)	120
Shells, classified and labelled	4,000
Crustacea	200
Insects	5,000
Radiates	150
Corals and sponges	250
	11,220

These 11,220 specimens, together with a botanical collection of Canadian and British plants, numbering 1,600 sheets, make up the total of 12,820 biological specimens. The geological collections comprise 1,500 rocks and fossils, besides 2,500 minerals, amongst which are some rare old finds. Of birds' eggs there is a collection of 160 specimens.

There is also the 'Ferrier collection' of Egyptian antiquities, presented in 1859; the 'C. U. Shepard collection' of minerals, numbering 600 specimens; and a rare collection of birds from the Malay Archipelago presented by H. J. Tiffin, Esq., in 1892.

The collections in this museum have been enriched from time to time by private donations, and much of the work in classification is due to Sir William Dawson, Mr. J. F. Whiteaves, the late Mr. E. Billings, and many others. This society received provincial aid for a number of years, but is now supported by the members of the Natural History Society of Montreal. Curator: J. B. Williams, Esq., 32 University Street, Montreal, Quebec.

Museum of the Geological Survey of Canada—the National Museum of Canada, Ottawa, Ontario.—Contains some 92,000 specimens, arranged and classified for reference. The finest and most complete collection of Canadian minerals, rocks, and fossils. The geological cabinets and cases include upwards of 14,000 specimens of minerals and rocks, illustrating the mines and mining industry of Canada, besides a typical collection of 16,000 fossil organic remains neatly labelled and classified, representing about 4,600 species, of which about 1,000 are the types of species described by the late E. Billings, and some 600 types described by Mr. Whiteaves. Other type specimens of fossil organic remains in the collection are the types of species established by Sir Wm. Dawson, Sir W. E. Logan, J. W. Salter, Dr. S. H. Scudder, Professor T. Rupert Jones, Professor E. O. Ulrich, Professor E. D. Cope, Professor H. Alleyne Nicholson, Dr. Henry Woodward, Professor James Hall, Dr. Arthur H.

[1] 600 of these are Canadian.

Foord, Mr. W. R. Billings, Dr. H. M. Ami, and Mr. L. M. Lambe. Among special suites may be mentioned fossils characterising the 'Quebec Group' of Logan and Billings from Quebec and Newfoundland.

About 150,000 specimens, illustrating the palæontological characters of the various geological formations in Canada, from Atlantic to Pacific, and from the United States boundary line to the Arctic Circle, are kept for reference in the store-room and basement of the museum, together with a series of duplicate specimens for collections intended for educational purposes.

There is also a remarkably fine collection of Ordovician Crinoidea from the Trenton of Ottawa and Hull, and a fine series of Devonian fishes from Bay des Chaleurs, and the original specimens of *Eozoon canadense.*

The zoological collections comprise 15,000 specimens, including the 'Whiteaves collection' of shells, Atlantic and Pacific coast shells of British North America—corals, radiates, and sponges from various localities—besides birds, mammals, reptiles, and the 'Geddes collection of Lepidoptera,' chiefly Rocky Mountain and Canadian.

Types: North Pacific and N. Atlantic recent sponges described by Mr. L. M. Lambe; Mollusca, foraminifera and other invertebrates described by Mr. J. F. Whiteaves, A. E. Verrill, J. B. Smith, Alex. Agassiz and others.

Ethnological collection includes the 'Mercier collection' (chiefly N.W. Eskimo); the 'Herschfelder collection' of Indian remains from Ontario; the Powell collection of Pacific or West Coast Indians of British Columbia, besides various collections made by officers of the Geological Survey of Canada.

Madoc Meteorite, Thurlow Meteorite (pars) also in the collection.

The herbarium contains upwards of 80,000 sheets, of which 50,000 form the most complete collection of Canadian plants. Besides numerous types and co-types of Canadian species described by Hooker, Michaux, Torrey, Pursh, Gray, Watson, Kindberg, Robinson, Peck, and other botanists, the herbarium comprises large and representative collections from Great Britain, Scandinavia, Northern Russia, France, Germany, Switzerland, Austria, Italy, Greenland, the United States of America, including Alaska, Mexico, Australia, New Zealand, Natal, &c. There are also included the classic herbaria prepared by Menzies, Sir Joseph Back, Sir John Richardson, Douglas, Drummond, and other arctic explorers in the early years of this century, besides a complete collection of Canadian woods and a fair collection of the native fruits from the Atlantic to the Pacific. The herbarium is in charge of Professor John Macoun, Dominion Botanist.

Director of the Museum: Dr. G. M. Dawson, C.M.G., F.R.S.

The Fisheries Museum, Ottawa, Canada.—Under the immediate care of the Department of Marine and Fisheries at Ottawa. Contains the best collection of Canadian fishes in the Dominion. This collection, primarily brought together in 1883 as part of the exhibit from Canada at the Fisheries Exhibition, London, England, gives a very fair idea of the fisheries of the large bodies of fresh and salt water of the Dominion from an economic standpoint. Specimens determined for the most part by Mr. J. F. Whiteaves, of the Geological Survey of Canada in 1883. Now in charge of Professor Ed. E. Prince, B.A., F.L.S., Commissioner of Fisheries for Canada, Ottawa.

Central Experimental Farm Museum, Ottawa, Ontario.—Contains a

good herbarium of Canada. Collections of native and cultivated fruits, seeds, &c., preserved in a liquid medium for reference for agricultural as well as horticultural purposes. Samples of the cereals, grasses, and fruits which grow in Canada as the result of tests made at the central and other experimental stations in Canada. Samples of soils from different portions of Canada and the North-West. Director : Dr. Wm. Saunders, F.R.S.C., Ottawa, Ontario. Maintained by the Dominion Government Territories, forming part of the Department of Agriculture. Collections of insects injurious and beneficial to vegetation. Botanical and entomological collections in charge of Dr. James Fletcher, Central Experimental Farm, Ottawa, Ontario.

Queen's University Museum, Kingston, Ontario.—Contains 22,700 specimens, arranged and classified for the use of professors and students. Of these there are 3,600 minerals and rocks and 5,000 fossil organic remains, in all 8,600 geological specimens. The zoological collections, chiefly mollusca and other invertebrata, number 3,146 specimens. Entomological and ethnological collections defective.

The herbarium is an excellent one, and contains 9,435 sheets of Phanerogamia and Cryptogamia of Canada and other countries. Type specimen : Large slab showing tracks of *Sauropus unguifer*, Dawson, from the Carboniferous rocks of Cumberland County, Nova Scotia.

Special collection : The 'Rev. Andrew Bell collection' of minerals, rocks, and fossils, consisting of 1,500 specimens. Curator : Rev. J. Fowler, M.A., F.R.S.C., Kingston, Ontario.

Museum of the School of Mining, Kingston, Ontario.—The mineral collection consists of about 9,000 specimens, classified as follows :—(1) Specimens to which students have access, 5,650 ; (2) specimens illustrating physical mineralogy, 900 ; (3) mineral species, 2,120, specimens ; (4) ores, &c.

The palæontological collections consist of the Columbian Exposition collection sent to Chicago by the Geological Survey of Canada, and presented to the Ontario School of Mining, together with a number of specimens of Ontario palæozoic fossils. Curator : Professor W. G. Miller, M.A., Ph.D.

Biological Museum, University of Toronto, Toronto, Ontario.—Contains between 15,000 and 20,000 specimens, of which the geological department includes about 12,000 specimens, as follows :—

Ferrier collection of minerals	6,000 specimens
Palæontological collections	4,000 ,,
Rocks, &c.	2,000 ,,

The zoological collections alone number 8,000 specimens, and include specimens of living and fossil representatives of the various classes and orders of the animal kingdom, as well as a large series of models for educational purposes. There is also a good herbarium, with collections of woods, models, &c., all of which serve to illustrate the botanical department in the university. The ethnological department, established by the late Sir Daniel Wilson, contains a large collection of crania and implements.

There are no types in the museum. Curators : Professor R. Ramsay Wright, M.A., Ph.D., Professor A. B. Macallum, M.A., C. Jeffrey, Esq., M.A.

Museum of the School of Practical Science, Toronto, Ontario.—Contains 6,000 specimens, of which 3,292 belong to the geological department, and are divided as follows :—

Minerals	1,245 specimens
Rocks	1,647 ,,
Fossil organic remains	400 ,,

Besides the above there is also a students' collection of 1,600 species for reference, and 1,200 thin or microscopic sections of rocks. Economic minerals a speciality. Curator: Professor A. P. Coleman, M.A., Ph.D., University College, Toronto, Ontario.

Museum of Victoria University, Toronto, Ontario.—3,000 specimens are included in the geological collections (500 mineral specimens, 500 rocks, and 2,000 specimens of fossil organic remains). There is also the 'Taylor collection of archæological remains' from both the eastern and western hemispheres. *Meteorite* from near Victoria, N.W.T. Curator: Rev. N. Burwash, D.D., Queen's Park, Toronto, Ontario.

Ontario Archæological Museum, Toronto, Ontario.—Supported since 1887 by an annual grant of $1,000 from the Ontario Legislature. Excellent collection of stone and clay pipes, copper and iron, and stone implements and weapons from various portions of the province of Ontario, besides collections from United States mounds, from British Columbia, &c. The collections in all amount to about 20,000 pieces (not counting individual wampum beads, &c.), thousands of flints, hundreds of celts (plain and grooved), gouges, hundreds of bone and horn instruments, numerous clay vessels, 200 crania, 700 miscellaneous Aztec specimens, 250 slate gorgets, 40 'bird' amulets, besides clay vessels from Aztec and Pueblo mounds.

The collection is neatly labelled and catalogued as to exact name of locality, name of donor, collector, and date. Curator: David Boyle, Esq., Ontario Archæological Museum, in connection with the Department of Education, Ontario.

Canadian Institute Museum, Toronto, Ontario.—Supported by legislative grant and membership fees. It is located at 58 Richmond Street East, Toronto. Established 1849; incorporated by Royal Charter, 1851. The specimens belonging to the old Natural History Society of Toronto (now the Biological Section of the Institute) form part of the Canadian Institute Museum collections. The zoological collections comprise the following:—

Birds (Canadian)	729	specimens
Birds' eggs (Canadian)	329	„
Birds (foreign)	150	„
Mammals	62	„
Reptiles	200	„
Insects	2,000	„

There is also a small herbarium. Curator: James H. Fleming, Esq., Canadian Institute.

Hamilton Association Museum, Hamilton, Ontario.—Contains 8,000 specimens, arranged and classified, of which there are about 3,300 geological, divided as follows:—Fossil organic remains, 2,500; minerals, 800. Fine collection of the sponges and graptolites of the Niagara formation, Canada. The herbarium contains 1,400 sheets, belonging chiefly to the local flora. Zoological collection defective, although some few and rare species are exhibited. Small collection of ethnological specimens from Canada and the South Sea Islands. The Mrs. S. E. Carry collections of 3,000 specimens of shells, recent and fossil, and of Indian relics form part of the exhibits at present in the musuem—a loan collection. Secretary (pro-Curator), S. A. Morgan, B.A., 26 Erie Avenue, Hamilton, Ontario.

Ontario Agricultural College Museum, Guelph, Ontario.—Contains

about 5,000 specimens : Minerals, 230 ; rocks, a small collection ; fossils, 65 ; zoological collection miscellaneous, and divided as follows :—

Birds	398	specimens
Reptiles	15	"
Fishes	38	"
Mollusca	102	"
Molluscoidea	3	"
Insects	767	"
Annuloida	18	"
Cœlenterata	11	"
Protozoa	1	"
In all	1,422	

The botanical collections, comprising dried plants and seeds for agricultural purposes, European plants, &c., contain 1,698 specimens and samples, besides a fair collection of Canadian woods.

Museum and college under the supervision of the Department of Education for Ontario, Dr. S. P. May, Toronto, organiser of the museum, and J. Hoyes Panton, officer in charge, Guelph Agricultural College, Guelph, Ontario.

Entomological Society of Ontario, London, Ontario.—Contains the leading collection of entomological specimens in Ontario. The Society has also a botanical and a geological section. Curators of the Museum : J. Moffatt, Esq., Professor Dearness, and S. Woolverton, London, Ontario.

Museum of the Literary and Historical Society of Manitoba, Winnipeg, Manitoba.—Contains several thousand specimens. The natural history collection comprises the birds, mammals, and insect fauna of the province and the North-West Territories of Canada. Very fair collection of minerals, rocks, and fossils from various geological formations in Manitoba and the other provinces. Housed in special apartments in the City Hall of Winnipeg. Curator : Charles N. Bell, Esq., City Hall, Winnipeg, Manitoba, Canada.

Provincial Museum, Winnipeg, Manitoba.—Contains several hundred specimens of fossils from the Trenton limestone of Manitoba, and from the Cretaceous shales of the North-West Territories. Located in the Parliament Buildings, Winnipeg, and supported by a grant from the Provincial Legislature.

Rocky Mountain Park Museum, Alberta, Canada.—Supported by the Dominion Government. The majority of the specimens exhibited were sent from the Geological Survey Department and Museum at Ottawa. Contains interesting collections of the birds, plants, woods, &c., of local interest to tourists and travellers. Illustrates the fauna and flora of the Rocky Mountain region of Canada. Superintendent : H. Douglas, Esq., Banff, Alberta, North-West Territories.

Provincial Museum, Victoria, British Columbia.—This is one of the best kept and most interesting collections in Canada. Upward of 11,000 specimens arranged and classified for reference. Good collections of rocks, minerals, and fossils of British Columbia and other parts of Canada. The Newton H. Chittenden collections in ethnology of special value and interest. Zoological collections fairly complete.

Types : Two type specimens of birds : (1) *Melospiza Lincolnii*, Brewster ; (2) *Zaprora salivus*, Jordan, from near Nanaimo, Gulf of Georgia, British Columbia. Curator : John Fannin, Esq., P.O. Box 471, Victoria, British Columbia.

Notes on Private Collections in Canada.

Halifax, Nova Scotia.

1. Dr. A. H. Mackay	Good reference collections in botany and zoology. Special collection of Canadian Spongillæ; also micro-organisms.
2. Andrew Downs, Esq.	Ornithological collection.
3. Harry Austin, Esq.	(Dartmouth) Ornithological collection.
4. T. J. Egan, Esq.	(Dalhousie University) Ornithology.
5. The Lawson Herbarium.	Containing the extensive series of mounted and dried plants of Nova Scotia and other parts of Canada, with special reference to the Ranunculaceæ and Filices of the whole Dominion.
6. Dr. John Somers	Herbarium.
7. Dr. Lindsay	Herbarium.

St. John, New Brunswick.

8. Dr. Lucien Allison	St. John and New Brunswick Diatomaceæ.
9. S. D. Scott, Esq.	Numismatic collection.
10. G. U. Hay, Esq., F.R.S.C.	New Brunswick and general Canadian plants.
11. A. Gordon Leavitt, Esq.	Collection of native birds for reference.
12. J. S. Maclaren, Esq.	Numismatic collection, collection of medals, clasps, &c.
13. Dr. G. F. Matthew, F.R.S.C.	Best collection of St. John group fossils. Palæozoic fossils from maritime provinces and other parts of Canada. Numerous types of species of fossil plants, sponges, mollusca, insecta, trilobita, &c., from various horizons (Cambrian, Ordovician, Silurian, and Devonian) in the Palæozoic of New Brunswick; European fossils; also recent plants and marine invertebrates.

Montreal, Quebec.

14. Dr. T. J. W. Burgess, F.R.S.C.	Herbarium contains about 15,000 sheets. Excellent and very complete collection of Canadian flowering plants, including North-West Territory and Rocky Mountain flora, 2,509 species. Ontario collection very complete. Canadian vascular cryptogamic plants, 7,000 sheets.
15. Sir Wm. Van Horne, K.C.M.G.	Extensive collection of fossil organic remains from Canada, the United States, and Europe.
16. Rev. Robert Campbell, D.D.	Herbarium containing plants representing flora of Montreal Island, Murray Bay, and other portions of the Province of Quebec.
17. Harold B. Cushing, B.A.	Complete collection of the ferns of the island of Montreal. Fair collection of Phanerogamia of Montreal Island and vicinity.
18. Dr. B. J. Harrington	Cabinets of minerals from Canada and the United States for reference collection. Type specimens, dawsonite, chemawinite, &c.

Ottawa, Ontario.

19. W. Hague Harrington, Esq., F.R.S.C.	Very complete collection of Ottawa Coleoptera and Hymenoptera; also Spiders and Proctotrypidæ. Contains numerous types of species new to science. Also collection of Canadian flowering plants.
20. Dr. James Fletcher, F.L.S., F.R.S.C.	Specimens illustrating his 'Ottawa Flora' or 'Flora Ottawaënsis' as published in the 'Transactions of the Ottawa Field Naturalists' Club.' Botanical collections from nearly all parts of the Dominion and elsewhere. Also extensive collections of insects injurious and beneficial to vegetation, &c. Excellent collection of Lepidoptera.

21. Walter R. Billings, Esq.	Very complete collection of Ordovician fossils from the Ottawa Valley, including those from Paquette's Rapids, Hull, and Ottawa City and vicinity.
22. W. L. Scott, Esq., B.A.	Excellent collection of birds and birds' eggs of Ottawa and vicinity.
23. George R. White, Esq.	Excellent collection of mounted birds and birds' skins for reference in Ottawa district.
24. Frank R. Latchford, Esq., B.A.	Collection of Ottawa Unionidæ contains *Unio borealis*, A. F. Gray, a type from the Ottawa River described from Mr. Latchford's collection. Also large series of Ohio and Western Ontario as well as other Canadian shells.
25. Dr. H. Beaumont Small	Good collection of the flowering plants about Ottawa and vicinity.
26. R. B. Whyte, Esq. .	Excellent reference collection of the flora of Ottawa and vicinity. Perth specimens. Species of rare occurrence in the collection.
27. Walter F. Ferrier, Esq., F.G.S.	Excellent collection of Canadian minerals. Also foreign type and other minerals. Collection of rocks—lithological. Canadian fossil organic remains.
28. Dr. H. M. Ami. .	Fair collection of Ottawa and general Canadian flowering plants. Foreign and domestic shells. Collection of Canadian ethnological specimens. Utica fossils from Ottawa and vicinity.
29. J. Burr Tyrrell, Esq., B.A., B.Sc., F.G.S.	Collection of Canadian Acaridæ and Arachnidæ. Contains types described by G. Haller, A. Poppe, F. Kœnicke, J. H. Emerton, J. W. Peckham, and J. B. Tyrrell.
30. W. J. Wilson, Esq., B.Sc.	Choice collection of Devonian fossil plants from the 'fern-ledges' of Lancaster Co., New Brunswick. Also two co-types of fossil insects described by Dr. G. F. Matthew.
31. Joseph Towsend, Esq.	Palæontological collections: 3,000 Guelph fossils; 1,000 Ordovician fossils from Trenton, Utica, and Lorraine of Ontario; 500 Niagara corals and other fossils; 400 pre-Glacial plants and shells.
32. T. W. E. Sowter, Esq.	(Aylmer, Quebec.) Collection of Chazy fossils from Aylmer and vicinity. Fair collections of Trenton and Black River fossils from the Ottawa Palæozoic Basin. Mr. Sowter's collections of Ordovician fossils include more than 2,000 specimens.

Vernon, Ontario.

33. Rev. J. M. Goodwillie, M.A.	Collection of archæological remains from Ontario; also Hamilton group, Niagara, Clinton, and Black River fossils from various districts in Ontario.

Kingston, Ontario.

34. Rev. Professor James Fowler, M.A., F.R.S.C.	Large herbarium, consisting of 14,731 sheets, representing flora of New Brunswick very completely, and that of other parts of British North America very well, besides foreign specimens.
35. W. G. Kidd, Esq., M.A.	Very good collection of the minerals of Ontario. This collection was exhibited at the World's Fair, Chicago, in 1893 as part of the Province of Ontario exhibit.

Lansdowne, Ontario.

36. Rev. W. G. Young, M.A.	Ornithological and Oological collection.

Toronto, Ontario.

37. B. E. Walker, Esq., F.G.S.	Extensive and choice collection of Canadian, Niagara, Hamilton group and Ordovician fossils. Also fine collection of British and United States fossils. Undescribed Stromatoporoids.
38. James H. Fleming, Esq.	2,000 bird-skins, including 500 species, nearly all Canadian birds. Also mounted birds from Canada and some foreign birds.
39. Hon. G. W. Allan .	Collection of native (Canadian) birds.

Hamilton, Ontario.

40. A. E. Walker, Esq. .	Collections of local fossils, including rare and undescribed fossil sponges from Silurian of the district.
41. A. T. Neill, Esq. .	Collections of fossils and minerals from Canada, ranging from the Laurentian to the Cretaceous.
42. Col. C. C. Grant .	Collection of Medina, Clinton, and Niagara fossils, graptolites and sponges a speciality. Also few Indian relics.
43. Thomas McIlwraith, Esq.	Complete collection of Canadian birds; also many foreign species.
44. A. Alexander, Esq. .	Botanical collection, local flora. Also Georgian Bay plants.

Grimsby, Ontario.

45. Jonathan Pettit, Esq.	Excellent collection of Niagara (Silurian) fossils, containing good crinoidea, &c.

Thedford, Ontario.

46. Rev. Hector Currie, M.A.	Very complete collection of Hamilton group fossils from Thedford (Widder), Bartlett's mills, &c., in Lambton County, Ontario.

London, Ontario.

47. Rev. W. Mintern Seaborn, M.A.	Collection of Devonian fossils, chiefly corals from Western Ontario.

Olds, N.W.T.

48. — Willing, Esq. .	Entomological collection, North-West noctuids. Type specimens and undescribed specimens in collection.

Victoria, British Columbia.

49. Dr. C. F. Newcombe.	Excellent collection of Cretaceous and Tertiary fossils from British Columbia, &c. Numerous undescribed forms, including decapod crustacea.
50. Rev. G. W. Taylor, M.A., F.R.S.C.	Canadian and British mollusca. Large and important reference collection of Western (especially) as well as Eastern recent shells (Nanaimo, B.C.).
51 John Fannin, Esq. .	General collection of fossil organic remains, from the Cretaceous and Tertiary of Vancouver and other islands, and recent natural history specimens from British Columbia (Victoria, B.C.).

Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee, consisting of Sir H. E. ROSCOE (*Chairman*), Dr. MARSHALL WATTS (*Secretary*), Sir J. N. LOCKYER, Professors J. DEWAR, G. D. LIVEING, A. SCHUSTER, W. N. HARTLEY, *and* WOLCOTT GIBBS, *and* Captain ABNEY. (*Drawn up by* Dr. WATTS.)

COBALT.

Hasselberg: 'Kongl. Svenska Vetenskaps-Akadem. Handl.,' Bd. 28, No. 6, 1896.
Exner and Haschek: 'Sitzber. kaiserl. Akad. Wissensch. Wien,' cv. (2), 1896.

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
*5531·06	7		1·51	4·9	18074·8
5525·27	5		,,	,,	18093·7
*5524·24	2		,,	,,	18097·1
*5523·56	6		,,	,,	18099·4
5516·29	3		,,	,,	18123·1
5495·94	4		1·50	5·0	18190·2
5489·90	6		,,	,,	18210·3
*5488·38	3		,,	,,	18215·3
*5484·22	6		,,	,,	18229·1
*5483·57	8	5483·70 Thalén	,,	,,	18231·3
5477·37	4		,,	,,	18251·9
*5477·13	6		,,	,,	18252·7
5470·73	4		1·49	,,	18274·1
5469·55	4		,,	,,	18278·0
*5454·79	7		,,	,,	18327·5
5453·61	2	5453·30 ,,	,,	,,	18331·5
5452·53	3		,,	,,	18335·1
*5444·81	7	5444·30 ,,	,,	,,	18361·1
*5437·25	4		1·48	,,	18390·0
5431·30	3		,,	,,	18406·8
5427·59	2		,,	,,	18419·4
5427 41	2		,,	,,	18420·0
5427·01	2		,,	,	18421·7
5425·87	3		,,	,,	18425·2
5408·37	3		,,	,,	18485·0
5407·75†	5		,,	,,	18487·0
*5402·24	4		,,	,,	18505·8
5400·03	3		1·47	,,	18513·4
5394·02	2		,,	5·1	18534·3
5391·01	2		,,	,,	18544·3
*5390·71	3		,,	,,	18545·3
*5381·99	5		,,	,,	18575·4
*5381·31	4		,,	,,	18577·7
*5377·99	2		,,	,,	18589·2
5374·21	2		,,	,,	18602·3
*5370·60	2		,,	,,	18614·8

* Coincident with a solar line.
† Solar line double, Co and Mn (Co > Mn).
‡ Observed also by Exner and Haschek in the spark spectrum.

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
*5369·79††	6s	5369·25 Thalén	1·47	5 1	18617·6
5369·13	3		"	"	18619·9
5366·97	3		"	"	18627·4
*5362·97	6	5363·75 "	1·46	"	18641·3
*5359·41	2	5360·75 "	"	"	18653·7
*5359·16	2		"	"	18654·5
5353·69§	3	5353·65 "	"	"	18673·6
*5352·22	5	5352·45 "	"	"	18678·7
5349·29	4		"	"	18689·3
5347·68	4		"	"	18694·6
5344·79	3		"	"	18704·7
*5343·58	6	5343·85 "	"	"	18708·9
*5342·86	8	5343·35 "	"	"	18711·5
5341·53	5s		"	"	18716·1
5339·71	4		"	"	18723·5
5337·56	2		"	"	18729·9
5336·36	3		"	"	18734·2
*5335·06	4 double		"	"	18738·8
*5333·85	4		"	"	18743·0
*5332·85	4		"	"	18746·6
*5331·65	5s		"	"	18750·8
5326·49	3		"	"	18769·0
5326·15	4		"	"	18770·2
*5325·44	5		1·45	"	18772·7
5321·95	3		"	"	18785·0
*5316·96†††	5		"	"	18802·6
*5312·84	5		"	"	18817·2
5310·47	3		"	"	18825·6
5301·24	5s		"	5·2	18858·3
5292·45	2		"	"	18889·6
5288·02	3		"	"	18905·5
5287·78	3		"	"	18906·3
*5283·68	3		"	"	18921·1
*5280·85	6	5280·69 "	"	"	18931·1
5276·38	5		"	"	18947·2
5268·72	5s	5268·79 "	"	"	18974·7
*5266·71	6	5266·79 "	1·44	"	18982·2
*5266·51	6		"	"	18982·7
*5266·00	3		"	"	18984·5
*5257·81	5		"	"	19014·1
5254·83	4		"	"	19024·9
5250·21	4		1·43	"	19041·6
*5248·12	5		"	"	19049·2
5237·32	2		"	"	19088·5
*5235·37	5s	5235·49 "	"	"	19095·6
*5230·38	5s	5231·09 "	"	"	19113·9
5222·71	3		"	"	19141·9
5219·28	2		"	"	19154·7
*5218·42	4		"	"	19157·7
*5212·87	5s	5213·09 "	1·42	"	19178·1

§ Solar line double { Co 5353·69. Fe 5353·59. †† Titanium 5369·81.

††† Solar line double { 5316·95 5316·75 } ; the corona line.

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
*5211·08	2		1·42	5·2	19184·7
5210·28	3s		,,	,,	19187·6
*5176·27	5s		,,	5·3	19313·6
5172·49	4n		1·41	,,	19328·7
5166·30	4		,,	,,	19350·9
*5165·32	4		,,	,,	19354·6
5159·03	4n		,,	,,	19378·2
5158·61	4n		,,	,,	19379·8
5156·53	5		,,	,,	19386·8
5155·04	3		,,	,,	19393·2
*5154·26	5		,,	,,	19396·1
*5153·43	3		,,	,,	19399·3
*5150·03	4		,,	,,	19412·1
*5149·32‖	3		,,	,,	19414·7
*5146·96	6		,,	,,	19423·6
*5145·73	4n		,,	,,	19428·2
*5142·65	3		,,	,,	19439·9
5133·65	6s		1·40	,,	19474·0
*5126·37	5s		,,	,,	19501·7
5125·88	5		,,	,,	19504·5
5124·99	3		,,	,,	19506·9
*5123·01	5		,,	,,	19514·5
*5113·41	5		,,	5·4	19551·0
*5109·08	5		,,	,,	19567·6
*5108·55	2		,,	,,	19569·6
*5105·73	4		,,	,,	19580·4
5100·30	3		1·39	,,	19601·3
*5095·18	5		,,	,,	19621·0
5088·08	3		,,	,,	19648·4
5077·64	3		,,	,,	19688·8
5035·16	2		1·38	,,	19854·9
5034·24	3		,,	,,	19858·6
5033·55	2		,,	,,	19861·3
*5022·37	3		1·37	5·5	19905·4
5007·49	3		,,	,,	19964·6
*4993·27	3		,,	,,	20022·3
4988·15§	5		1·36	,,	20042·0
4986·69	3		,,	,,	20047·9
4980·15	5		,,	,,	20074·2
4974·75	3		,,	,,	20096·0
4972·16	5		,,	,,	20106·5
4971·22	3		,,	,,	20110·3
*4968·09	3n		,,	,,	20123·0
*4967·72	2		,,	,,	20124·5
4966·77	5		,,	,,	20128·3
4959·89	2		,,	,,	20156·2
*4953·37	4		1·35	,,	20182·8
4948·77	3		,,	,,	20201·9
4942·56	2		,,	5·6	20226 8
4941·53	2		,,	,,	20231·0
4936·61	3		,,	,,	20251·2
4935·40	2		,,	,,	20256·2
4933·08	3		,,	,,	20265·7

‖ Also Mn. § Double.

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
*4928·48‖	6		1·35	5·6	20284·6
4925·20	3		,,	,,	20298·2
4920·47	4		,,	,,	20317·6
*4912·62	3		1·34	,,	20350·1
4908·68	3		,,	,,	20366·5
4907·78	2		,,	,,	20370·2
4907·30	2		,,	,,	20372·2
4904·37	5		,,	,,	20381·4
4899·72	6		,,	,,	20403·7
4897·36	4		,,	,,	20413·6
*4887·19	4		,,	,,	20472·8
4882·90	6		,,	,,	20474·0
4880·43	2		,,	,,	20484·4
4878·53	3		1·33	,,	20492·4
*4869·59	4		,,	,,	20530·0
*4868·05	10	4867·90 Thalén	,,	,,	20536·4
4863·64	3		,,	,,	20555·1
4862·29	3		,,	,,	20560·4
*4855·86	2		,,	5·7	20587·9
4855·40	3		,,	,,	20589·9
*4843·61	5		,,	,,	20640·1
*4840·42§	9	4839·90 ,,	1·32	,,	20653·7
*4818·13	3		,,	,,	20749·2
*4816·11	4		,,	,,	20757·9
4814·16	6	} 4814·40 ,,	,,	,,	20766·4
*4813·67	9		,,	,,	20768·5
4798·01	3		1·31	,,	20836·3
†4797·93	3		,,	,,	20836·6
4796·46	4		,,	,,	20843·0
4796·00	5		,,	,,	20845·0
*4793·03	8	4792·54 ,,	,,	,,	20857·9
4785·26	5		,,	,,	20891·8
4782·76	3		,,	,,	20902·7
4781·62	6		,,	5·8	20907·9
*4780·14	8	4779·54 ,,	,,	,,	20914·1
*4778·42	5		,,	,,	20921·6
*4776·49	7		,,	,,	20930·1
*4771·27	7		,,	,,	20957·4
*4768·26	6		,,	,,	20966·2
4767·33	5		,,	,,	20970·3
4756·93	4		1·30	,,	21016·2
*4754·59	6		,,	,,	21026·5
*4749·89	9	4749·34 ,,	,,	,,	21047·3
4746·31	4		,,	,,	21063·2
4742·76	2		,,	,,	21079·0
4742·40	2		,,	,,	21080·6
4738·34	2		,,	,,	21098·6
4737·95	5		,,	,,	21100·4
4735·04	5		,,	,,	21113·3
4732·25	3		,,	,,	21125·8
4728·14	6		1·29	5·9	21144·1
4727·95	3		,,	,,	21144·9

‖ See Titanium.

§ Solar line double $\begin{cases}\text{Fe } 4840·50\\ \text{Co } 4840·42\end{cases}$ $\begin{cases}4814·10\\ 4814·35\end{cases}$

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4725·44	2		1·29	5·9	21156·1
4721·61	3		,,	,,	21173·3
*4718·67	5		,,	,,	21186·9
4704·57	3		,,	,,	21250·0
4699·35	4		,,	,,	21273·6
*4698·60	6		,,	,,	21277·0
*4697·19	3		,,	,,	21283·4
‡4693·37	7		,,	,,	21300·7
4688·68	3		1·28	,,	21322·1
4686·05	3		,,	,,	21334·0
‡*4682·53	8		,,	,,	21350·1
4680·62	3		,,	,,	21358·8
4677·73	3		,,	,,	21372·0
4677·46	3		,,	,,	21373·3
4676·91	3		,,	,,	21375·7
4668·04	3		,,	,,	21416·4
‡4663·58	8		,,	,,	21436·9
*4657·56	5		,,	,,	21464·6
4655·01	4		1·27	,,	21476·3
4653·93	3		,,	,,	21481·3
4652·01	3		,,	,,	21490·2
‡4651·28	3		,,	,,	21493·6
*4645·34‖	3		,,	,,	21521·5
*4644·48	5		,,	,,	21525·0
4643·92	4		,,	,,	21527·6
4640·99	3		,,	,,	21541·6
‡*4629·47‖	9		,,	6·0	21594·8
4629·05	4		,,	,,	21596·7
‡4625·88	6		,,	,,	21611·5
4624·70	3		,,	,,	21617·0
‡4623·15	5		,,	,,	21624·3
4622·83	3		,,	,,	21625·9
4620·96	3		,,	,,	21634·5
4614·18§	4		1·26	,,	21666·3
4612·57	2n		,,	,,	21673·9
4609·08	3		,,	,,	21690·3
*4607·46	4		,,	,,	21697·9
4601·31	4		,,	,,	21726·9
‡*4597·02	8		,,	,,	21747·2
‡*4594·75	8		,,	,,	21758·0
*4588·86	4s		,,	,,	21785·9
4587·08	3s		,,	,,	21794·4
‡4581·76§	10	4581·75 Thalén	,,	,,	21819·7
4580·32	5		1·25	,,	21826·5
4575·12	3		,,	,,	21851·4
4573·75	2		,,	,,	21857·9
‡4570·18	6		,,	,,	21875·0
4566·77	5		,,	,,	21891·3
‡4565·74	9		,,	,,	21896·2
4564·98	3		,,	,,	21899·9
4564·35	4s		,,	6·1	21902·8
4564·13	3		,,	,,	21903·9
4562·11	3		,,	,,	21913·6

‖ See Titanium.

§ Solar line double { 4581·69. 4581·59.

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4553·51	3		1·25	6·1	21955·0
‡*4549·80¶	8		,,	,,	21972·9
4547·06	3		,,	,,	21986·1
*4546·14	5		,,	,,	21990·6
‡4545·42	4		,,	,,	21994·1
‡*4543·99	7		,,	,,	22001·0
4540·96	3		1·24	,,	22015·7
‡*4534·18	8		,,	,,	22048·3
‡*4531·14	10	4531·45 Thalén	,,	,,	22063·1
‡4528·12	5		,,	,,	22078·1
‡4526·94	3		,,	,,	22083·9
*4525·97	3		,,	,,	22089·9
*4524·88	3		,,	,,	22093·9
4519·42	4n		,,	,,	22119·6
*4517·28	7		,,	,,	22131·1
*4514·33	5		,,	,,	22145·6
4500·71	2		1·23	,,	22212·6
4499·45	2		,,	,,	22218·8
‡4494·92	5s		,,	6·2	22241·1
4492·23	3		,,	,,	22254·5
4490·46	3		,,	,,	22263·2
4486·89	4s		,,	,,	22281·0
4484·65	4s		,,	,,	22292·1
‡*4484·07	5s		,,	,,	22294·5
4483·70	5n		,,	,,	22296·8
‡*4478·45	6		,,	,,	22322·9
4477·36	3n		,,	,,	22328·4
‡4471·96	4		,,	,,	22355·4
‡4471·70	6		,,	,,	22356·7
‡*4469·72	8		,,	,,	22366·6
‡*4467·04	7		1·22	,,	22380·0
‡4445·88	5		,,	,,	22486·5
‡4445·21	4		,,	,,	22489·9
4442·13	2		,,	,,	22505·5
*4438·05	2		,,	,,	22526·2
*4436·37	3		,,	,,	22534·7
‡4431·78	4		,,	6·3	22558·0
4421·48	5s		1·21	,,	22611·6
‡4417·55	6		,,	,,	22630·7
*4416·63	3		,,	,,	22635·4
‡*4402·85	4		,,	,,	22706·3
*4395·99	4		,,	,,	22741·7
‡*4392·02	5		1·20	,,	22762·3
‡*4391·70	6		,,	,,	22763·9
‡*4388·02	4		,,	,,	22783·0
‡*4380·25	6n		,,	,,	22823·4
*4379·37‖	3		,,	,,	22828·0
‡4375·70	4		,,	,,	22847·2
‡*4375·09	5		,,	,,	22850·4
*4374·66	3		,,	,,	22852·6
‡*4373·77	6		,,	,,	22857·3
‡4371·27	6		,,	,,	22870·3

¶ Solar line double $\begin{cases}4549·65\\4549·80\end{cases}$, a Titanium line at 4549·79.

‖ Perhaps due to Vanadium.

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4366·37	3		1·20	6·4	22895·9
4362·11	2		,,	,,	22918·3
‡4361·20	2		,,	,,	22923·1
*4360·98	3		,,	,,	22924·2
*4359·60	3		,,	,,	22931·5
‡4357·33	2		,,	,,	22943·4
*4357·05	4		,,	,,	22944·9
*4353·96	3		1·19	,,	22961·2
4340·39	2		,,	,,	23033·0
‡4339·76	6		,,	,,	23036·3
4331·38	5		,,	,,	23080·9
*4320·53	3n		,,	,,	23138·9
4310·24	2		1·18	,,	23194·2
‡*4309·54	4		,,	,,	23197·9
‡4307·57	4		,,	6·5	23208·4
‡*4303·36	5		,,	,,	23231·2
4298·14	3n		,,	,,	23259·4
‡*4292·41	4n		,,	,,	23290·4
‡*4285·93	5s		,,	,,	23325·7
*4276·25	4		1·17	,,	23378·5
4270·58	3		,,	,,	23409·5
‡4268·59	4		,,	,,	23420 4
4268·18	3		,,	,,	23422·7
‡4263·92	3		,,	,,	23446·1
*4260·05	3		,,	,,	23467·4
‡*4252·47	6		,,	6·6	23509·1
‡4248·37	3		,,	,,	23531·8
‡4245·76	3n		,,	,,	23546·3
4242·06	4		1·16	,,	23566·9
*4241·69	4		,,	,,	23568·9
*4238·63	3		,,	,,	23585·9
*4237·54	3		,,	,,	23592·0
‡*4234·18	5		,,	,,	23610·7
*4230·15	2		,,	,,	23633·2
‡*4225·28	3		,,	,,	23660·5
‡*4215·03	2		,,	,,	23718·0
‡4210·26	2		,,	,,	23744·9
‡4207·77	3		,,	,,	23759·0
4198·58	3		1·15	6·7	23811·0
4198·01	2		,,	,,	23814·2
*4193·01	2		,,	,,	23842·6
‡*4190·87	6		,,	,,	23854·7
‡*4187·44	4		,,	,,	23874·2
‡4171·02	4		,,	,,	23968·2
‡4162·33	5		1·14	,,	24018·3
‡*4158·58	5		,,	,,	24040·0
‡*4150 59	4		,,	,,	24086·3
‡4139·58	4		,,	6·8	24150·2
‡4122·42	4		1·13	,,	24250·8
‡*4121·47	9		,,	,,	24256·4
‡*4118·92§	9		,,	,,	24271·4
‡*4110·69	8		,,	,,	24320·0

§ Solar line double $\begin{cases} 4118·92 \text{ Co.} \\ 4119·02 \end{cases}$

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	1/λ−	
4110·21	4		1·13	6·8	24322·9
4109·83	2		,,	,,	24325·1
4104·89	4		,,	,,	24354·4
*4104·57	4s		,,	,,	24356·3
4097·37	4		,,	6·9	24399·0
4096·08	4		,,	,,	24406·7
*4093·20	4		1·12	,,	24423·9
*4092·98	4		,,	,,	24425·2
‡*4092·55§	8		,,	,,	24427·7
‡*4086·47	7		,,	,,	24464·1
*4085·74	3		,,	,,	24468 5
*4084·28	3		,,	,,	24477·2
‡*4082·76	5		,,	,,	24486·3
4081·63	3		,,	,,	24493·1
‡*4077·55	5		,,	,,	24517·6
4076·74	4		,,	,,	24522·5
4076·28	5s		,,	,,	24525·3
4069·70	3		,,	,,	24564·9
‡*4068·72	6s		,,	,,	24570·8
‡*4066·52	6s		,,	,,	24584·1
‡*4058·75	5s		,,	,,	24631·2
*4058·36	5s		,,	,,	24633·6
‡4057·36	4s		,,	,,	24639·7
‡4057·10	4		,,	,,	24641·2
‡4054·08	4		1·11	,,	24659·6
‡*4053·08	5		,,	,,	24665·7
‡4049·43	3		,,	7·0	24687·8
‡*4045·53	8		,,	,,	24711·6
*4040·96	4		,,	,,	24739·6
*4040·76	3		,,	,,	24740·8
‡4035·73	7		,,	,,	24771·7
‡*4027·21	6		,,	,,	24824·1
‡*4023·54	3		,,	,,	24846·7
‡*4021·05	7		,,	,,	24862·1
‡*4019·47	4		,,	,,	24871·9
‡*4014·12	4		1·10	,,	24905·1
‡*4011·08	2		,,	,,	24923·9
‡*3998·04	8	3997·94 L. & D.	,,	7·1	25005·1
*3995·45§‡‡	9	3995·33 ,,	,,	,,	25021·4
*3994·65	3		,,	,,	25026·4
‡*3991·82	4	3992·04 ,,	,,	,,	25044·1
3991·69	4		,,	,,	25044·9
‡3990·45	4	3990·84 ,,	,,	,,	25052 7
‡3987·26	4	3987·74 ,,	,,	,,	25072·8
‡*3979·65	6	3979·34 ,,	,,	,,	25120·7
3979·03	3n		,,	,,	25124·6
‡*3978·80	6		,,	,,	25126·1
‡3977·36	3		,,	,,	25135·2
‡3975·48	3		1·09	,,	25147·1

‡‡ Exner and Haschek's numbers: 3995·52.

§ Solar line double {4092·45. / 4092·56 Co.} {3995·456. / 3995·35.}

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
‡*3974·87	6	3974·74 L. & D.	1·09	7·1	25150·9
‡*3973·29	3		,,	,,	25161·0
‡3972·66	4		,,	,,	25164·9
‡3969·25	5	3969·44 ,,	,,	,,	25186·6
‡3961·14	4		,,	,,	25238·2
‡*3958·06	6	3958·34 ,,	,,	,,	25257·8
*3957·79	2		,,	,,	25259·5
‡*3953·05	7	3953·04 ,,	,,	7·2	25289·7
‡3952·47	4		,,	,,	25293·4
‡*3947·28	3		,,	,,	25326·7
‡*3945·47	6	3945·53 ,,	,,	,,	25338·3
‡*3941·87	6	3941·53 ,,	,,	,,	25361·5
‡*3941·01	5		,,	,,	25367·0
‡*3936·12§	8	3936·13 ,,	1·08	,,	25398·5
‡*3934·05	4		,,	,,	25411·9
‡3933·32	2		,,	,,	25416·6
‡3929·42	4		,,	,,	25441·8
‡3925·32	3		,,	,,	25468·4
‡*3922·88	5s		,,	,,	25484·3
3921·24	3		,,	,,	25494·9
‡*3920·89§§	4s		,,	,,	25497·2
‡3920·28	4		,,	,,	25501·2
3919·79	3		,,	,,	25504·4
‡3917·26	5	3916·83 ,,	,,	,,	25520·8
‡*3915·66	2		,,	,,	25531·3
‡*3910·08§	7	3909·63 ,,	,,	,,	25567·7
‡*3906·42	6	3905·83 ,,	,,	7·3	25591·6
‡*3904·20	4		,,	,,	25606·1
‡*3898·64§	4		,,	,,	25642·7
‡*3895·12	7	3994·93 ,,	1·07	,,	25665·8
*3894·21‡‡	10nr	3994·03 ,,	,,	,,	25671·8
3893·44	3		,,	,,	25676·9
‡*3893·19	2s		,,	,,	25678·6
‡3892·26	3		,,	,,	25684·7
‡3891·83	3		,,	,,	25687·6
‡*3885·40	4s		,,	,,	25730·1
‡*3884·76	5	3884·63 ,,	,,	,,	25734·3
‡*3882·04§	7	3881·63 ,,	,,	,,	25752·4
‡*3881·18	3		,,	,,	25758·1
‡*3880·54	3		,,	,,	25762·3
‡*3876·99	6	3876·72 ,,	,,	,,	25785·9
*3874·10‡‡	7n	3873·82 ,,	,,	,,	25805·1
*3873·25‡‡	9n	3873·02 ,,	,,	,,	25810·9
‡*3870·65	4s		,,	,,	25828·2
*3866·92	2		,,	,,	25853·1
‡3863·72	3		,,	,,	25874·5

§§ Solar line triple $\begin{cases}\text{3920·99 Fe.}\\ \text{3920·89 Co.}\\ \text{3920·75 Fe.}\end{cases}$

‡‡ Exner and Haschek's numbers: 3894·13, 3874·05, 3873·17.

§ Solar line double $\begin{cases}\text{3936·12 Co.}\\ \text{3935·95.}\end{cases}$ $\begin{cases}\text{3882·12}\\ \text{3882·04 Co}\end{cases}$ $\begin{cases}\text{3910·08 Co}\\ \text{3909·98 Fe}\end{cases}$ $\begin{cases}\text{3898·65 Co.}\\ \text{3898·55.}\end{cases}$

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
‡*3861·29	6	3861·12 L. & D.	1·07	7·3	25890·8
*3860·55‖	4		,,	,,	25895·7
‡3856·93	4s		1·06	,,	25920·1
‡*3851·97	4		,,	,,	25953·4
‡3851·09	5s		,,	,,	25959·4
3850·24	3		,,	,,	25965·1
*3845·59‡‡	9nr	3845·42 ,,	,,	,,	25996·5
‡*3843·90	4		,,	,,	26007·9
*3842·20‡‡	7n	3842·02 ,,	,,	,,	26019·5
‡*3841·60	4s		,,	,,	26023·5
‡3836·04	3		,,	,,	26061·2
‡3835·82	3		,,	,,	26062·7
‡*3833·02	3		,,	,,	26081·8
‡3820·02	4		,,	7·4	26170·6
‡3818·08	3		,,	,,	26183·9
‡3817·02	4		,,	,,	26191·2
‡*3816·58	5	3816·31 ,,	1·05	,,	26194·2
‡*3816·46	5	3815·72 ,,	,,	,,	26195·0
‡3814·58	4		,,	,,	26207·9
‡*3812·57	3		,,	,,	26221·7
‡*3811·16	3		,,	,,	26231·4
‡*3808·24	4	3807·91 ,,	,,	,,	26250·5
‡*3805·90	3		,,	,,	26267·7
‡3777·65	4	3777·60 ,,	,,	,,	26464·2
‡3774·72	4	3774·60 ,,	1·04	,,	26484·7
‡3760·52	3		,,	7·5	26584·7
‡3759·83	3		,,	,,	26589·4
‡*3755·59	5s		,,	,,	26619·5
‡3754·50	3	3754·30 ,,	,,	,,	26627·2
‡3752·95	2		,,	,,	26637·9
‡*3751·75	4		,,	,,	26646·7
‡*3750·06	5		,,	,,	26658·7
‡3745·61	7	3746·40 ,,	,,	,,	26689·4
3740·31	4		,,	,,	26728·3
‡*3736·30	5	3735·80 ,,	1·03	,,	26756·9
‡*3734·30	5s		,,	,,	26771·3
‡*3733·62	5	3733·40 ,,	,,	,,	26776·2
‡*3732·52¶	6		,,	,,	26784·1
‡*3731·42	2		,,	,,	26792·0
‡*3730·61§§	5	3730·40 ,,	,,	,,	26797·8
‡*3726·80	3		,,	7·6	26825·1
‡*3712·31	4	3712·20 ,,	,,	,,	26929·8
‡*3711·80	3		,,	,,	26933·5
*3708·96	5		,,	,,	26954·1
‡*3707·61§	4		,,	,,	26964·0
‡*3704·17	6	3704·10 ,,	,,	,,	26989·0
‡*3702·40	5	3702·30 ,,	,,	,,	27001·9

‖ Also Manganese.
‡‡ Exner and Haschek's numbers: 3845·57, 3842·12.

¶ Also Iron.

§§ Solar line triple { 3730·60 Co.; 3730·50, 3730·43 } Fe.

§ Solar line double { 3707·70 Ti.; 3707·60 Co. }

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
*‡3693·65	5s	3693·39 L. & D.	1·02	7·6	27065·9
*3693·53	3		,,	,,	27066·8
‡3693·27	5	3692·99 ,,	,,	,,	27068·7
‡*3690·87	4s	3690·79 ,,	,,	,,	27086·3
‡3686·63	3		,,	,,	27117·4
‡3685·13	3		,,	,,	27128·5
‡*3684·62	5		,,	,,	27132·2
‡*3683·18¶	7	3683·09 ,,	,,	7·7	27142·8
‡*3676·69	6		,,	,,	27190·7
‡*3670·20	3		,,	,,	27238·8
‡3662·33		3662·38 ,,	,,	,,	27297·3
‡*3658·05¶	3		,,	,,	27329·3
‡*3657·12	4s	3656·68 ,,	1·01	,,	27336·2
‡*3654·59	4s	3654·58 ,,	,,	,,	27355·2
‡*3652·68	5		,,	,,	27369·5
‡3651·42	4s		,,	,,	27378·9
‡*3649·47¶	6	3649·38 ,,	,,	,,	27393·5
‡3648·30	4		,,	,,	27402·3
‡3647·82	5		,,	,,	27405·9
‡*3647·25	4		,,	,,	27410·2
‡3645·60	3		,,	,,	27422·6
‡3645·36	4		,,	,,	27424·4
‡3643·34	5	3643·28 ,,	,,	,,	27439·6
‡*3641·95	5	3641·68 ,,	,,	,,	27450·1
‡*3639·63§	5	3639·48 ,,	,,	,,	27467·6
‡3637·49	4s		,,	7·8	27483·7
‡*3636·89	4s	3636·68 ,,	,,	,,	27495·7
‡*3634·86	5	3634·78 ,,	,,	,,	27503·6
‡3633·52	3s		,,	,,	27513·7
‡*3633·00	5	3632·78 ,,	,,	,,	27517·7
‡3632·12	4		,,	,,	27524·3
‡3631·55	6		,,	,,	27528·7
‡*3627·96	7	3627·88 ,,	,,	,,	27555·9
‡*3625·13	5		,,	,,	27577·4
*3624·48	4		,,	,,	27582·4
‡*3620·59	4		,,	,,	27612·0
‡3618·17	3		,,	,,	27630·5
‡*3615·56	4	3615·38 ,,	1·00	,,	27650·4
‡*3611·89	5	3611·88 ,,	,,	,,	27678·5
‡*3609·92	3		,,	,,	27693·6
3608·50	3		,,	,,	27704·6
‡*3605·50§	6	3605·58 ,,	,,	,,	27727·6
‡*3605·19	4		,,	,,	27730·0
‡*3604·62	4		,,	,,	27734·4
3600·99	3		,,	,,	27763·1
‡*3596·67	4		,,	,,	27795·7
*3595·00‡‡	7r	3594·98 ,,	,,	7·9	27808·5
‡*3591·92	3		,,	,,	27832·5
‡3589·44	2		,,	,,	27851·6

§ Solar line double { 3605·62 Fe / 3605·50 Co | 3586·30 Fe. / 3586·20 Co.

¶ Also Iron.

‡‡ Exner and Haschek's number: 3595·00.

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
*3587·30‡‡	10nr	3587·28 L. & D.	1·00	7·9	27868·2
*3586·20§	3		„	„	27876·8
‡3585·92	3		„	„	27878·9
‡*3585·28	7r		„	„	27883·9
‡*3584 92	5s		„	„	27886·7
‡3582·00	4		„	„	27909·5
‡3579·16	4		„	„	27931·6
3579·01	4		„	„	27932·8
‡*3578·20	4	3577·98 „	„	„	27939·1
3577·80	3		0·99	„	27942·2
*3577·36	3		„	„	27945·7
‡*3575·48	7nr	3575·47 „	„	„	27960·4
‡*3575·06	6nr	3575·07 „	„	„	27963·7
*3569·48‡‡	10nr	3569 47 „	„	„	28007·4
*3568·36	3		„	„	28016·2
‡*3565·08	6r	3565·07 „	„	„	28042·0
‡*3564·25	4		„	„	28048·5
‡*3563·04	5s		„	„	28058·0
*3562·22	5s		„	„	28064·5
*3561·01‡‡	6r	3561·07 „	„	„	28074·0
‡3560·44	4		„	„	28078·5
‡*3558·90	5s		„	„	28090·7
*3553·28	3		„	„	28135·1
‡*3553·12 } ‖	5		„	„	28136·4
‡*3552·85 }	4	3552·97 „	„	„	28138·5
‡*3550·72	6r	3550·67 „	„	8·0	28155·3
‡*3548·60	5	3548·57 „	„	„	28172·1
‡*3546·86	4		„	„	28186·0
‡*3543·40	6s	3543·37 „	„	„	28213·5
‡3534·92	4		0·98	„	28281·2
*3533·49‡‡	7r	3533·37 „	„	„	28292·6
*3529·92‡‡	9nr	3529·87 „	„	„	28321·3
‡*3529·17	6	3528·96 „	„	„	28327·3
*3526·96‡‡	9nr	3526·86 „	„	„	28345·0
*3525·97	3		„	„	28353·0
*3523·85	5		„	„	28370·0
*3523·57‡‡§	6r	3523·46 „	„	„	28372·3
‡*3523·00	4		„	„	28376·9
*3521·70‡‡	6r	3521·46 „	„	„	28387·4
‡*3520·20	6	3520·06 „	„	„	28399·5
*3519·90	4		„	„	28401·9
*3518·49‡‡	7	3518·26 „	„	„	28413·3
*3513·62‡‡	7		„	„	28452·7
*3512·78‡‡	7	3512·56 „	„	„	28459·5

§ Solar line double { 3605·62 Fe / 3605·50 Co } { 3586·30 Fe / 3586·20 Co } { 3523·57 Co. / 3523·47 }

‡‡ Exner and Haschek's numbers: 3587·36, 3569·58, 3560·97, 3533·46, 3529·96, 3527·00, 3523·60, 3521·70, 3518·53, 3513·58, 3512·80.

‖ Solar line triple { 3553·12 Co. / 3552·98 Fe. / 3552·85 Co. }

COBALT—*continued.*

Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
*3510·53‡‡§	7	3510·26 L. & D.	0·98	8·1	28477·6
*3509·98‡‡§	7	3509·86 "	"	"	28482·1
*3506·44‡‡	8nr	3506·16 "	"	"	28510·8
‡3505·28	3		"	"	28520·3
‡3504·88	4		"	"	28523·5
*3503·86	3	3503·96 "	"	"	28531·9
‡*3502·76	6nr	3502·56 "	"	"	28540·9
*3502·41‡‡	9nr	3502·16 "	"	"	28543·7
‡*3496·83§	6r	3496·56 "	0·97	"	28589·2
*3495·82‡‡	7	3495·66 "	"	"	28597·1
‡*3492·15	3		"	"	28627·6
‡*3491·46	5	3491·16 "	"	"	28633·2
‡3490·89	5		"	"	28638·0
*3489·54‡‡	8r	3489·36 "	"	"	28649·0
‡*3487·86	4		"	"	28662·8
‡*3485·49	7	3485·25 "	"	"	28682·3
‡*3483·55	6r	3483·25 "	"	"	28698·2
‡3480·16	3		"	"	28726·2
*3478·90	4	3478·55 "	"	"	28736·6
‡*3478·69	4		"	"	28738·5
‡*3478·01	3		"	"	28744·0
‡*3476·49	4	3476·55 "	"	"	28756·5
*3474·66§	4		"	"	28771·7
*3474·15‡‡	8nr	3473·95 "	"	"	28775·9
‡*3471·52§	5		"	"	28797·7

SPARK SPECTRUM.

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3469·2	2		0·97	8·2	28817
3468·7	2		"	"	28821
3468·3	2		"	"	28825
3467·7	2		"	"	28830
3467·5	2		"	"	28831
3465·96	8		"	"	28843·8
3465·5	2		"	"	28848
3463·01	8		"	"	28868·4
3461·3	4		"	"	28883
3460·5	2		"	"	28890
3458·5	2		0·96	"	28906
3457·8	2		"	"	28912

* Double.

‡‡ Exner and Haschek's numbers: 3510·52, 3509·92, 3506·45, 3502·30, 3495·78, 3489·58, 3474·11.

§ Solar line double $\left\{\begin{array}{l}\text{3471·52 Co.}\\ \text{3471·47 Fe.}\end{array}\right.$

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3457·1	4		0·96	8·2	28918
3456·6	2		,,	,,	28922
3456·2	2		,,	,,	28926
3455·6	2n		,,	,,	28931
3455·4	5		,,	,,	28932
3453·71	8		,,	,,	28946·2
3453·0	4		,,	,,	28952
3452·6	2		,,	,,	28956
3452·1	2		,,	,,	28960
3451·8	2		,,	,,	28962
*3451·3	2		,,	,,	28967
3449·62	7		,,	,,	28980·5
3449·32	7		,,	,,	28983·0
3447·5	2		,,	,,	28999
3447·3	2		,,	,,	29000
3446·5	6		,,	,,	29007
3445·6	2n		,,	,,	29014
3443·82	7		,,	,,	29029·3
3443·4	2		,,	,,	29033
3443·2	5		,,	,,	29035
3442·2	2		,,	,,	29043
3441·4	2		,,	,,	29050
3441·3	2		,,	,,	29051
3440·8	2		,,	,,	29055
3439·0	4		,,	,,	29070
3438·0	2		,,	,,	29079
3437·2	2		,,	,,	29085
3435·9	2		,,	,,	29096
3435·6	2		,,	,,	29099
3433·18	7		,,	8·3	29120·1
3432·5	2		,,	,,	29125
3431·73	7		,,	,,	29131·5
3431·1	2		,,	,,	29137
3430·9	2		,,	,,	29139
3430·0	2		,,	,,	29147
3429·5	2		,,	,,	29151
3429·0	2		,,	,,	29155
3428·5	4		,,	,,	29159
3426·6	2		,,	,,	29175
3424·7	4		,,	,,	29192
*3424·0	4		,,	,,	29198
3423·0	2		,,	,,	29206
3421·9	2		,,	,,	29216
3421·0	2		,,	,,	29223
3417·9	4		0·95	,,	29250
3417·32	7		,,	,,	29254·4
3415·9	5		,,	,,	29267
3414·9	6		,,	,,	29275
3413·7	2		,,	,,	29286
3412·80	7		,,	,,	29293·2
3412·48	7		,,	,,	29295·9
3411·7	2		,,	,,	29304
3409·32	7		,,	,,	29323·0
3407·1	2		,,	,,	29343
3405·28	8		,,	,,	29357·9

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3403·7	2		0·95	8·3	29372
3403·3	2		,,	,,	29375
3402·3	2		,,	,,	29384
3402·2	2		,,	,,	29385
3402·0	2n		,,	,,	29386
3399·3	2n		,,	,,	29410
3399·0	2		,,	,,	29416
3395·50	7		,,	8·4	29442·3
3393·1	4		,,	,,	29464
3391·2	4		,,	,,	29480
3390·6	2		,,	,,	29485
3388·30	7		,,	,,	29504·8
3387·8	5		,,	,,	29510
3385·4	5		,,	,,	29531
3384·1	2		,,	,,	29542
3382·3	2		,,	,,	29558
3381·7	2		,,	,,	29563
3381·2	2		,,	,,	29567
3378·9	4		,,	,,	29587
3378·5	2		0·94	,,	29591
3377·2	4		,,	,,	29602
3376·4	2		,,	,,	29609
3375·2	2n		,,	,,	29620
3374·8	2		,,	,,	29623
3374·4	4		,,	,,	29627
3374·2	2		,,	,,	29629
3373·4	4		,,	,,	29636
3372·2	2		,,	,,	29646
3371·1	5		,,	,,	29656
3370·5	4		,,	,,	29661
3369·7	4		,,	,,	29668
3368·8	2		,,	,,	29676
3367·3	5		,,	,,	29690
3366·4	2		,,	,,	29697
3366·0	2		,,	,,	29701
3365·3	2n		,,	,,	29707
3364·5	2		,,	,,	29709
3363·9	2		,,	,,	29719
3363·4	2		,,	,,	29724
3363·0	4		,,	,,	29727
3361·7	4		,,	,,	29739
3361·5	2b		,,	8·5	29741
3360·5	2b		,,	,,	29749
3359·4	4		,,	,,	29759
3358·8	4		,,	,,	29765
3358·3	2n		,,	,,	29769
3357·0	2		,,	,,	29780
3356·6	2		,,	,,	29784
3356·1	2		,,	,,	29788
3355·3	2		,,	,,	29796
3354·48	7		,,	,,	29802·4
3352·9	4		,,	,,	29817
3351·7	2		,,	,,	29828
3351·3	2n		,,	,,	29831
3350·5	2		,,	,,	29838

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3348·3	4		0·94	8·5	29858
3347·1	4		,,	,,	29869
3346·4	2		,,	,,	29875
3344·2	2		,,	,,	29895
3342·9	4		,,	,,	29906
3342·1	2		,,	,,	29913
3341·5	4		,,	,,	29918
3340·0	4		,,	,,	29932
3337·3	2		0·93	,,	29956
3336·6	2		,,	,,	29963
3334·3	5		,,	,,	29983
3333·5	4		,,	,,	29990
3329·6	4		,,	,,	30026
3328·4	2		,,	,,	30036
3327·1	4		,,	,,	30048
3325·4	4		,,	8·6	30066
3324·0	2		,,	,,	30076
3323·0	2		,,	,,	30085
3322·3	5		,,	,,	30092
3320·5	2		,,	,,	30107
3320·0	2		,,	,,	30111
3319·6	4		,,	,,	30115
3319·4	2		,,	,,	30117
3318·6	2		,,	,,	30124
3315·2	2		,,	,,	30155
3314·2	5		,,	,,	30164
3313·3	2		,,	,,	30172
3313·1	2		,,	,,	30174
3312·3	4		,,	,,	30181
3308·9	2		,,	,,	30213
3308·6	2		,,	,,	30215
3307·3	4		,,	,,	30227
3306·5	2		,,	,,	30234
3305·8	2		,,	,,	30241
3305·2	2		,,	,,	30246
3304·9	2		,,	,,	30249
3304·2	2		,,	,,	30255
3304·0	2		,,	,,	30257
3303·4	2n		,,	,,	30263
3301·9	2n		,,	,,	30277
3301·3	2n		0·92	,,	30282
3298·8	4		,,	,,	30305
3297·6	2b		,,	,,	30316
3296·6	2b		,,	,,	30325
3294·7	2		,,	,,	30343
3294·1	2		,,	,,	30348
3293·5	2		,,	,,	30354
3292·2	2		,,	,,	30366
3290 6	2b		,,	,,	30381
3287·7	2		,,	8·7	30407
3287·4	4		,,	,,	30410
3286·0	2n		,,	,,	30423
3283·9	2		,,	,,	30451
3283·57	7		,,	,,	30446·0
3282·3	2b		,,	,,	30457

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3281·5	2n		0·92	8·7	30465
3279·4	4		"	"	30484
3279·0	2		"	"	30488
3278·3	2		"	"	30495
3277·8	4		"	"	30499
3277·5	4		"	"	30502
3276·6	4n		"	"	30510
3274·10	7		"	"	30534·0
3272·0	5		"	"	30553
3271·4	2		"	"	30561
3270·5	2		"	"	30567
3269·7	2		"	"	30575
3269·3	2		"	"	30579
3268·2	2n		"	"	30589
3267·9	2n		"	"	30592
3265·5	2		"	"	30514
3265·0	4		"	"	30619
3262·5	4		"	"	30642
3261·8	2n		"	"	30649
3261·2	2n		"	"	30655
3260·9	6		"	"	30657
3260·0	2n		0·91	"	30666
3258·5	2		"	"	30680
3258·2	4		"	"	30683
3256·5	2		"	"	30699
3254·3	6		"	"	30720
3250·1	4		"	8·8	30759
3247·70	7		"	"	30782·2
3247·30	7		"	"	30785·4
3247·2	2		"	"	30787
3246·3	2		"	"	30795
3246·0	2		"	"	30798
3245·7	2		"	"	30801
3245·5	2		"	"	30803
3244·2	5		"	"	30815
3243·8	2		"	"	30819
3239·1	2n		"	"	30864
3238·5	2n		"	"	30869
3238·0	2n		"	"	30874
3237·2	4		"	"	30882
3235·7	4		"	"	30896
3234·7	2		"	"	30906
3234·3	2		"	"	30910
3231·0	2		"	"	30941
3228·8	2		"	"	30962
3228·2	2		"	"	30968
3227·1	4		"	"	30979
3226·3	2n		"	"	30986
3225·3	4		"	"	30996
3224·8	4		"	"	31001
3221·8	2		"	"	31030
3221·4	2n		"	"	31033
3219·2	4		0·90	"	31055
3218·0	2		"	"	31066
3217·2	2		"	"	31074

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3217·0	2		0·90	8·8	31076
3215·4	2		,,	8·9	31091
3214·2	2		,,	,,	31103
3213·5	2		,,	,,	31110
3212·1	2		,,	,,	31123
3210·9	4		,,	,,	31135
3210·3	4		,,	,,	31141
3206·2	2		,,	,,	31181
*3204·1	2		,,	,,	31201
3203·2	2		,,	,,	31210
3202·3	2		,,	,,	31219
3200·5	2		,,	,,	31236
3199·4	2		,,	,,	31247
3198·7	2		,,	,,	31254
3198·5	2b		,,	,,	31256
3197·2	2		,,	,,	31268
3197·0	2		,,	,,	31270
3196·6	2		,,	,,	31274
3196·2	2		,,	,,	31278
3194·1	2b		,,	,,	31299
3193·2	2		,,	,,	31308
3192·3	2		,,	,,	31316
3191·3	2		,,	,,	31326
3189·8	2		,,	,,	31341
3188·5	5		,,	,,	31354
3186·4	4		,,	,,	31374
3186·0	4		,,	,,	31378
3184·4	2		,,	,,	31394
3182·2	4		0·89	,,	31416
3180·4	2		,,	9·0	31434
3180·1	2		,,	,,	31437
3179·6	2		,,	,,	31441
3177·3	5		,,	,,	31464
3175·0	4		,,	,,	31488
3174·2	4		,,	,,	31495
3173·2	2		,,	,,	31505
3172·1	2n		,,	,,	31516
3171·4	2b		,,	,,	31523
3169·8	5		,,	,,	31539
3168·1	4		,,	,,	31556
3164·6	2		,,	,,	31591
3163·7	2		,,	,,	31600
3161·7	4		,,	,,	31620
3161·2	2		,,	,,	31625
3159·8	4		,,	,,	31639
3158·8	5		,,	,,	31655
3156·7	2n		,,	,,	31670
3155·8	2		,,	,,	31679
*3154·82	7		,,	,,	31688·6
3152·8	4		,,	,,	31709
3150·8	2n		,,	,,	31729
3149·4	4		,,	,,	31743
3147·1	5		,,	9·1	31766
3144·1	2		,,	,,	31797
3140·7	2		0·88	,,	31831

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3140·0	5		0·88	9·1	31838
3137·9	2		,,	,,	31859
3137·4	5		,,	,,	31865
3136·9	2		,,	,,	31870
3132·3	2		,,	,,	31916
3130·9	4		,,	,,	31931
3129·6	2		,,	,,	31944
3129·1	2		,,	,,	31949
3127·4	2		,,	,,	31966
3126·9	2		,,	,,	31972
3126·7	2		,,	,,	31974
3123·0	2b		,,	,,	32011
3121·6	5		,,	,,	32026
3121·5	5			,,	32027
3118·4	4		,,	,	32059
3116·8	2n		,,	,,	32075
3115·8	2n		,,	,,	32085
3115·2	2n		,,	,,	32092
3114·5	2		,,	9·2	32099
3114·3	4		,,	,,	32101
3113·6	4		,,	,,	32108
3112·3	2		,,	,,	32122
3111·4	2		,,	,,	32131
3110·9	2		,,	,,	32136
3110·7	2n		,,	,,	32138
3110·2	4		,,	,,	32143
3109·6	4		,,	,,	32149
3109·3	2		,,	,,	32153
3107·6	2		,,	,,	32170
3107·2	2		,,	,,	32174
3105·9	2		,,	,,	32188
3105·5	2		,,	,,	32192
3104·1	2		,,	,,	32206
3103·8	4		,,	,,	32210
3102·5	4		,,	,,	32223
3100·9	2		0·87	,,	32240
3100·6	2		,,	,,	32243
3100·2	2		,,	,,	32247
3099·2	2		,,	,,	32257
3098·3	4		,,	,,	32267
3097·3	2		,,	,,	32277
3096·9	2		,,	,,	32281
3096·5	2		,,	,,	32286
3095·8	2		,,	,,	32293
3093·3	2n		,,	,,	32319
3090·4	4		,,	,,	32349
3089·7	4		,,	,,	32361
3088·7	2		,,	,,	32367
3088·0	2		,,	,,	32374
3086·9	6		,,	,,	32386
3086·6	4		,,	,,	32389
3082·9	2n		,,	9·3	32428
3082·7	6		,,	,,	32430
3081·0	4		,,	,,	32448
3079·5	4		,,	,,	32464

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3078·7	2n		0·87	9·3	32472
3077·8	2n		,,	,,	32482
3077·3	2n		,,	,,	32487
3076·3	2		,,	,,	32498
3073·6	4		,,	,,	32526
3072·4	6		,,	,,	32539
3072·1	4		,,	,,	32542
3071·0	2		,,	,,	32554
3068·7	2		,,	,,	32578
3066·5	2		,,	,,	32601
3064·7	4		,,	,,	32621
3064·5	4		,,	,,	32623
3063·6	2		,,	,,	32632
3062·3	2n		0·86	,,	32646
3061·9	6		,,	,,	32650
3061·0	2		,,	,,	32660
3060·1	4		,,	,,	32670
3058·6	2		,,	,,	32686
3056·8	2		,,	,,	32705
3055·2	2		,,	,,	32722
3054·8	2		,,	,,	32726
3053·0	2		,,	9·4	32746
3050·6	2		,,	,,	32771
3050·2	2		,,	,,	32776
3048·9	5		,,	,,	32790
3048·3	2		,,	,,	32796
3046·3	2		,,	,,	32818
3044·10	7		,,	,,	32841·0
3042·6	4		,,	,,	32858
3041·9	2		,,	,,	32865
3041·7	2		,,	,,	32867
3041·0	2		,,	,,	32875
3039·7	2		,,	,,	32889
3036·8	2		,,	,,	32920
3035·5	2		,,	,,	32935
3034·7	5		,,	,,	32943
3034·5	4		,,	,,	32945
3034·2	2		,,	,,	32949
3032·6	2n		,,	,,	32966
3032·0	2		,,	,,	32973
3031·4	2		,,	,,	32979
3031·2	2n		,,	,,	32981
3028·4	2n		,,	,,	33012
3026·7	2n		,,	,,	33030
3026·5	5		,,	,,	33032
3024·5	2		,,	9·5	33053
3023·7	2		0·85	,,	33062
3022·8	2b		,,	,,	33072
3022·5	2		,,	,,	33075
3020·1	2		,,	,,	33101
3019·9	2		,,	,,	33104
3019·3	2		,,	,,	33111
3017·7	6		,,	,,	33128
3017·5	2		,,	,,	33130
3015·8	2		,,	,,	33149

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
3013·7	5		0·85	9·5	33172
3011·7	2		,,	,,	33194
3011·2	2n		,,	,,	33199
3010·1	2		,,	,,	33211
3008·9	4		,,	,,	33225
3008·3	2		,,	,,	33231
3006·1	2		,,	,,	33256
3005·8	2		,,	,,	33259
3005·0	2b		,,	,,	33268
3001·7	2b		,,	,,	33304
3000·7	4		,,	,,	33316
2999·8	2		,,	,,	33326
2996·7	2		,,	9·6	33360
2995·2	4		,,	,,	33377
2990·4	2		,,	,,	33430
2989·7	6		,,	,,	33438
2988·2	2		,,	,,	33455
2987·2	6		,,	,,	33466
2982·3	2		0·84	,,	33521
*2981·7	4		,,	,,	33528
2978·1	2		,,	,,	33568
2975·6	2		,,	,,	33597
2973·3	4		,,	,,	33623
2971·7	2b		,,	9·7	33641
2971·1	2n		,,	,,	33648
2968·7	2		,,	,,	33675
2968·3	2n		,,	,,	33679
2965·3	2n		,,	,,	33713
2964·8	2n		,,	,,	33719
2963·0	2n		,,	,,	33740
*2961·7	2n		,,	,,	33754
2961·3	2		,,	,,	33759
2961·0	2		,,	,,	33762
2959·7	2		,,	,,	33777
2957·8	2		,,	,,	33799
2955·5	2		,,	,,	33825
2954·83	8		,,	,,	33833·2
2954·0	2		,,	,,	33842
2944·0	2		,,	9·8	33957
2943·2	6n		,,	,,	33967
2942·5	2		0·83	,,	33975
2942·2	2		,,	,,	33978
2934·1	2		,,	,,	34072
2933·7	2		,,	,,	34077
2930·5	5n		,,	,,	34114
2929·7	4		,,	,,	34123
2929·0	2		,,	,,	34131
2928·1	2		,,	,,	34142
2927·8	4		,,	,,	34145
2927·0	2		,,	,,	34155
2925·6	2n		,,	,,	34171
2924·8	2n		,,	,,	34180
2924·2	2n		,,	,,	34187
2921·7	2b		,,	,,	34217
2919·7	2		,,	9·9	34240

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2918·7	5n		0·83	9·9	34252
2916·7	2n		,,	,,	34275
2916·2	2n		,,	,,	34281
2915·5	2n		,,	,,	34289
2914·7	2		,,	,,	34299
2913·7	2		,,	,,	34311
2912·1	2n		,,	,,	34329
2911·6	2n		,,	,,	34335
2910·1	2n		,,	,,	34353
2908·9	2n		,,	,,	34367
2907·7	2n		,,	,,	34381
2907·0	2		,,	,,	34390
2905·6	2n		,,	,,	34406
2905·2	2n		,,	,,	34411
2904·3	2		,,	,,	34422
2903·8	2n		0·82	,,	34428
2903·2	2		,,	,,	34435
2899·9	2		,,	,,	34474
2898·8	2		,,	,,	34487
2897·9	2n		,,	,,	34498
2895·9	2		,,	10·0	34522
2895·5	2		,,	,,	34526
2895·3	2		,,	,,	34529
2894·9	2		,,	,,	34534
2892·4	2n		,,	,,	34563
2890·5	6		,,	,,	34586
2889·7	4		,,	,,	34596
2888·6	2n		,,	,,	34609
2886·5	4		,,	,,	34634
2883·8	2		,,	,,	34666
2883·5	2		,,	,,	34670
2882·3	2		,,	,,	34684
2882·0	2		,,	,,	34688
2880·5	2b		,,	,,	34706
2879·7	2n		,,	,,	34716
2878·6	2		,,	,,	34729
2876·9	2		,,	,,	34750
2876·6	2		,,	,,	34753
2874·2	2		,,	,,	34782
2874·1	2		,,	,,	34785
2873·5	2		,,	,,	34791
2873·0	2		,,	,,	34797
2872·6	2		,,	10·1	34802
2871·28	7		,,	,,	34817·6
2870·2	4n		,,	,,	34831
2868·3	2n		,,	,,	34854
2867·5	2n		,,	,,	34864
2866·7	2n		,,	,,	34873
2865·6	2n		,,	,,	34887
2862·7	2		0·81	,,	34922
2861·5	2n		,,	,,	34937
2859·7	2		,,	,,	34959
2858·5	2		,,	,,	34973
2857·3	2b		,,	,,	34988
2856·2	2		,,	,,	35002

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2855·8	2		0·81	10·1	35006
2853·5	2b		,,	,,	35035
2852·2	2		,,	,,	35051
2851·0	2		,,	,,	35065
2850·1	2		,,	,,	35078
2849·7	2		,,	,,	35081
2848·4	2b		,,	10·2	35097
2845·8	4		,,	,,	35129
2844·2	2		,,	,,	35149
2840·8	2		,,	,,	35191
2838·0	2b		,,	,,	35226
2837·3	4		,,	,,	35235
2835·8	2		,,	,,	35253
2835·1	4		,,	,,	35262
2834·5	2		,,	,,	35270
2834·0	2		,,	,,	35276
2831·7	2		,,	,,	35304
2828·7	2n		,,	,,	35342
2827·4	2		,,	,,	35358
2827·0	2		,,	,,	35363
2825·3	6		,,	,,	35384
2823·7	2		0·80	10·3	35405
2823·3	2b		,,	,,	35410
2821·9	2n		,,	,,	35427
2820·1	2		,,	,,	35450
2819·5	2		,,	,,	35457
2819·0	4		,,	,,	35464
2818·8	2		,,	,,	35466
2818·2	2		,,	,,	35474
2817·2	2		,,	,,	35486
2816·3	4b		,,	,,	35498
2815·9	2		,,	,,	35503
2815·7	4		,,	,,	35505
2813·4	2		,,	,,	35534
2813·0	2		,,	,,	35539
2812·7	2n		,,	,,	35543
2811·7	2		,,	,,	35556
2811·0	5		,,	,,	35565
2809·5	2		,,	,,	35584
2809·2	2		,,	,,	35587
2807·2	4		,,	,,	35613
2807·1	2		,,	,,	35614
2805·8	2		,,	,,	35630
2805·6	2		,,	,,	35633
2804·7	2		,,	,,	35644
2804·2	2n		,,	,,	35651
2803·9	4		,,	,,	35655
2802·7	4		,,	,,	35670
2802·3	2b		,,	,,	35675
2801·2	2		,,	,,	35689
2799·2	2		,,	10·4	35714
2799·0	2		,,	,,	35717
2798·5	4		,,	,,	35723
2797·2	4		,,	,,	35740
2797·0	4		,,	,,	35743

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2796·3	4		0·80	10·4	35752
2794·9	4		,,	,,	35769
2794·0	5b		,,	,,	35781
2791·7	2		,,	,,	35810
2791·1	2		,,	,,	35818
2789·6	2		,,	,,	35837
2786·1	4		,,	,,	35882
2785·6	4		,,	,,	35889
2782·8	2		0·79	,,	35925
2782·3	2n		,,	,,	35931
2781·6	2		,,	,,	35941
2780·1	2		,,	,,	35960
2779·6	2		,,	,,	35966
2779 0	4		,,	,,	35974
2778·3	2		,,	,,	35983
2776·3	6		,,	,,	36009
2775·2	4b		,,	10·5	36023
2774·0	2		,,	,,	36039
2773·0	2		,,	,,	36052
2771·0	2b		,,	,,	36078
2769·2	4		,,	,,	36101
2767·0	4n		,,	,,	36130
2766·4	4		,,	,,	36138
2764·9	2		,,	,,	36158
2763·9	4		,,	,,	36171
2763·2	2b		,,	,,	36180
2762·4	2b		,,	,,	36190
2762·1	2		,,	,,	36194
2761·6	2		,,	,,	36201
2761·5	2		,,	,,	36202
2760·5	2		,,	,,	36215
2758·6	2		,,	,,	36231
2758·4	2		,,	,,	36242
2758·0	2		,,	,,	36247
2757·4	2		,,	,,	36255
2754·7	2b		,,	,,	36291
2752·4	2		,,	,,	36321
2751·0	2		,,	10·6	36331
2750·4	2b		,,	,,	36347
2748·6	2		,,	,,	36371
2745·3	4		,,	,,	36415
2742·5	2		,,	,,	36452
2742·2	2		,,	,,	36456
2741·6	2		0·78	,,	36464
2740·5	2		,,	,,	36479
2739·2	4		,,	,,	36496
2738·5	2		,,	,,	36505
2737·5	2		,,	,,	36519
2737·2	2		,,	,,	36523
2734·9	4b		,,	,,	36553
2733·8	2		,,	,,	36568
2733·2	4		,,	,,	36576
2731·3	4		,,	,,	36604
2731·0	2		,,	,,	36606
2729·4	2n		,,	,,	36627

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2729·0	2n		0·78	10·6	36632
2728·1	4n		,,	,,	36645
2724·6	2		,,	,,	36692
2723·7	2		,,	,,	36704
2723·0	2n		,,	10·7	36713
2722·2	2		,,	,,	36724
2721·1	4		,,	,,	36739
2720·0	2		,,	,,	36754
2719·1	2		,,	,,	36766
2717·3	2n		,,	,,	36792
2716·5	2		,,	,,	36801
2716·1	4		,,	,,	36807
2713·5	2b		,,	,,	36842
2711·9	2n		,,	,,	36864
2710·4	2		,,	,,	36884
2709·2	4n		,,	,,	36900
2708·1	4		,,	,,	36915
2707·6	4n		,,	,,	36922
2706·8	6n		,,	,,	36934
2706·0	2		,,	,,	36944
2704·3	2		,,	,,	36967
2702·5	4		,,	,,	36992
2701·8	2		,,	,,	37001
2700·6	2		,,	,,	37018
2698·0	2		0·77	10·8	37053
2697·1	4		,,	,,	37066
2695·9	2		,,	,,	37082
2694·75	8		,,	,,	37098·4
2693·1	4n		,,	,,	37121
2692·4	2n		,,	,,	37131
2689·8	4		,,	,,	37167
2689·2	2b		,,	,,	37175
2687·0	2b		,,	,,	37205
2686·3	2b		,,	,,	37215
2685·4	2		,,	,,	37227
2684·6	5n		,,	,,	37239
2683·5	2n		,,	,,	37254
2682·8	2n		,,	,,	37264
2682·2	2		,,	,,	37272
2682·0	2		,,	,,	37275
2680·5	4		,,	,,	37296
2680·3	2		,,	,,	37298
2679·9	2		,,	,,	37304
2678·2	4		,,	,,	37328
2676·2	5n		,,	,,	37356
2674·0	2		,,	10·9	37372
2673·7	2		,,	,,	37390
2673·3	2		,,	,,	37396
2672·3	4b		,,	,,	37410
2670·8	4		,,	,,	37431
2669·9	4b		,,	,,	37444
2668·3	2b		,,	,,	37466
2666·3	2		,,	,,	37494
2665·3	2		,,	,,	37508
2663·58	8		,,	,,	37532·6

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2662·7	2n		0·77	10·9	37545
2662·2	2n		,,	,,	37552
2658·1	2		,,	,,	37610
2656·5	4b		,,	,,	37633
2653·74	7		0·76	,,	37671·8
2652·8	4		,,	11·0	37685
2652·4	2		,,	,,	37691
2650·3	2		,,	,,	37721
2648·70	7		,,	,,	37743·3
2646·5	2		,,	,,	37775
2643·2	2		,,	,,	37821
2641·2	2n		,,	,,	37851
2641·0	2n		,,	,,	37853
2640·5	2		,,	,,	37861
2639·3	2n		,,	,,	37878
2638·1	2		,,	,,	37895
2637·9	2		,,	,,	37898
2637·4	4		,,	,,	37905
2636·1	4		,,	,,	37924
2634·9	4		,,	,,	37941
2632·30	8		,,	,,	37978·6
2631·4	4		,,	11·1	37993
2631·1	4		,,	,,	37996
2630·5	2		,,	,,	38004
2628·8	2		,,	,,	38029
2627·7	2		,,	,,	38045
2627·0	2n		,,	,,	38055
2625·5	2		,,	,,	38077
2625·3	4		,,	,,	38080
2624·5	2n		,,	,,	38091
2624·0	2		,,	,,	38099
2623·7	2		,,	,,	38103
2622·6	2		,,	,,	38119
2622·4	2		,,	,,	38122
2622·0	4n		,,	,,	38128
2621·0	2b		,,	,,	38142
2619·8	4		,,	,,	38160
2618·8	4		,,	,,	38174
2615·3	2b		,,	,,	38226
2614·39	7		,,	,,	38238·7
2613·5	5		,,	,,	38252
2612·6	4n		,,	,,	38265
2610·4	2		,,	,,	38297
2609·0	2		0·75	11·2	38318
2608·1	2		,,	,,	38331
2605·9	5		,,	,,	38363
2605·7	5		,,	,,	38366
2604·5	4		,,	,,	38384
2603·3	2		,,	,,	38411
2600·9	2		,,	,,	38437
2594·4	2		,,	,,	38534
2594·2	2		,,	,,	38537
2593·8	4		,,	,,	38542
2593·5	2		,,	,,	38547
2591·5	2		,,	,,	38577

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2589·1	4n		0·75	11·2	38612
2587·25	8		,,	11·3	38639·8
2585·3	2		,,	,,	38669
2583·2	4		,,	,,	38700
2582·30	8n		,,	,,	38713·9
2581·4	2		,,	,,	38728
2580·38	8n		,,	,,	38742·7
2575·6	2b		,,	,,	38815
2574·9	5		,,	,,	38825
2574·5	4		,,	,,	38833
2572·3	2		,,	,,	38865
2569·8	4		,,	,,	38903
2569·0	2		,,	,,	38915
2567·4	4		,,	11·4	38939
2567·0	2		,,	,,	38945
2565·5	4		,,	,,	38968
2564·18	8		0·74	,,	38987·4
2562·7	2		,,	,,	39010
*2562·3	2		,,	,,	39016
2561·0	2		,,	,,	39036
2560·10	7		,,	,,	39050
2559·48	8		,,	,,	39059·0
2558·6	2		,,	,,	39073
2557·4	4		,,	,,	39091
2556·8	4		,,	,,	39103
2555·2	2		,,	,,	39125
2554·2	2		,,	,,	39140
2554·0	2		,,	,,	39143
2553·3	2		,,	,,	39154
2553·0	2		,,	,,	39159
2552·4	4		,,	,,	39168
2550·6	2n		,,	,,	39195
2549·9	2n		,,	,,	39206
2549·4	2n		,,	,,	39214
2548·6	2		,,	11·5	39226
2548·4	2		,,	,,	39229
2546·80	7		,,	,,	39253·5
2546·3	4		,,	,,	39262
2545·8	2		,,	,,	39269
2545·1	4		,,	,,	39280
2544·6	4		,,	,,	39288
2544·3	4		,,	,,	39293
2543·8	2		,,	,,	39300
2543·4	2		,,	,,	39316
2542·00	8n		,,	,,	39328·0
2540·7	6		,,	,,	39344
2540·3	2		,,	,,	39354
2538·9	2		,,	,,	39376
2537·6	2		,,	,,	39396
2536·8	2		,,	,,	39409
2536·6	2		,,	,,	39412
2536·1	4		,,	,,	39420
2535·7	2		,,	,,	39426
2535·4	2		,,	,,	39431
2534·5	2n		,,	,,	39445

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2534·0	6		0·74	11·5	39452
2533·8	4		,,	,,	39455
2531·9	2n		,,	,,	39485
2530·1	5		,,	11·6	39512
2529·6	2		,,	,,	39520
2529·1	2		,,	,,	39528
2528·68	7		,,	,,	39534·7
2528·3	4		,,	,,	39540
2526·2	2		,,	,,	39573
2525·08	7		,,	,,	39591·1
2524·7	4		,,	,,	39597
2523·0	4		,,	,,	39623
2521·5	5		,,	,,	39647
2521·0	2		,,	,,	39655
2519·90	8		,,	,,	39672·5
2517·9	2		0·73	,,	39704
2517·5	4		,,	,,	39710
2515·6	2		,,	,,	39740
2514·0	2		,,	,,	39765
2513·1	2		,,	,,	39780
2512·4	2		,,	,,	39791
2512·2	2		,,	,,	39794
2511·9	2		,,	11·7	39798
2511·23	7		,,	,,	39808·0
2509·3	2		,,	,,	39840
2508·1	4		,,	,,	39859
2506·8	2		,,	,,	39879
2506·51	8		,,	,,	39884·4
2505·7	2n		,,	,,	39897
2504·0	2		,,	,,	39924
2500·9	2		,,	,,	39974
2500·6	2		,,	,,	39978
2498·8	5		,,	,,	40007
2497·6	4		,,	,,	40026
2496·8	2		,,	,,	40039
2495·5	2		,,	,,	40060
2494·7	2		,,	,,	40073
2493·6	2		,,	11·8	40101
2492·4	2		,,	,,	40110
2492·2	2		,,	,,	40113
2491·4	2		,,	,,	40126
2491·2	2		,,	,,	40129
2490·8	2		,,	,,	40136
2490·4	5		,,	,,	40142
2487·4	4		,,	,,	40191
2487·2	4		,,	,,	40194
2486·5	6		,,	,,	40205
2485·4	5		,,	,,	40223
2484·4	2		,,	,,	40239
2484·3	2		,,	,,	40241
2484·1	2		,,	,,	40244
2483·6	4		,,	,,	40252
2483·3	2		,,	,,	40257
2482·2	2		,,	,,	40275
2480·2	2		,,	,,	40307

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2479·1	4		0·73	11·8	40325
2478·5	2		〃	〃	40335
2478·2	4		〃	〃	40340
2477·4	4		〃	〃	40353
2477·3	4		〃	〃	40355
2476·6	2		〃	11·9	40366
2476·4	2		〃	〃	40369
2473·1	2		〃	〃	40423
2472·9	2		〃	〃	40426
2471·8	2b		〃	〃	40444
2470·3	2		〃	〃	40469
2469·5	4		0·72	〃	40482
2467·0	5		〃	〃	40523
2464·2	6		〃	〃	40569
2462·1	2		〃	〃	40604
2461·8	2		〃	〃	40608
2461·2	2		〃	〃	40619
2460·2	2		〃	〃	40635
2459·3	4		〃	12·0	40650
2456·2	2		〃	〃	40701
2455·5	2n		〃	〃	40713
2454·5	2		〃	〃	40729
2454·2	2		〃	〃	40734
2453·8	2		〃	〃	40741
2453·3	4		〃	〃	40749
2452·5	4		〃	〃	40763
2451·6	2n		〃	〃	40778
2450·0	6		〃	〃	40804
2449·2	4		〃	〃	40818
2447·8	6		〃	〃	40841
2446·6	2		〃	〃	40861
2446·0	6		〃	〃	40871
2443·8	6		〃	12·1	40908
2442·6	6		〃	〃	40928
2441·7	4		〃	〃	40943
2441·1	2n		〃	〃	40953
2439·0	4		〃	〃	40988
2438·4	2n		〃	〃	40998
2438·0	4		〃	〃	41005
2437·0	4		〃	〃	41022
2436·7	2		〃	〃	41027
2436·3	2		〃	〃	41034
2435·1	4		〃	〃	41054
2434·2	2		〃	〃	41069
2432·6	5		〃	〃	41096
2432·3	4		〃	〃	41101
2431·7	2		〃	〃	41111
2430·8	2		〃	〃	41127
2430·6	2		〃	〃	41130
2429·9	4		〃	〃	41142
2429·5	2		〃	〃	41149
2428·4	4		〃	〃	41167
2426·6	2		〃	12·2	41198
2426·2	4		〃	〃	41205
2425·0	4		〃	〃	41225

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
*2423·7	4		0·72	12·2	41247
2422·6	2n		,,	,,	41266
2422·1	2		,,	,,	41274
2421 0	2		0·71	,,	41293
2420·8	4		,,	,,	41297
2419·3	2		,,	,,	41322
2418·5	4		,,	,,	41336
2417·7	4		,,	,,	41350
2417·0	4		,,	,,	41362
2416·0	4		,,	,,	41379
2415·3	4		,,	,,	41391
2414·5	2		,,	,,	41404
2414·2	4		,,	,,	41410
2411·6	4		,,	12·3	41454
2409·5	2n		,,	,,	41490
2408·8	4		,,	,,	41502
2408·4	4		,,	,,	41509
2407·7	4		,,	,,	41521
2407·5	4n		,,	,,	41525
2406·3	2n		,,	,,	41546
2406·0	2n		,,	,,	41551
2405·2	2		,,	,,	41565
2404·6	4		,,	,,	41575
2404·3	4		,,	,,	41580
2403·8	4		,,	,,	41589
2402·9	2		,,	,,	41604
2402·1	2		,,	,,	41618
2401·6	2		,,	,,	41627
2399·1	2		,,	,,	41670
2398·4	4		,,	,,	41682
2397·4	6		,,	12·4	41700
2396·8	2		,,	,,	41710
2395·5	4		,,	,,	41733
2394·5	4		,,	,,	41750
2394·0	2		,,	,,	41759
2392·6	4		,,	,,	41784
2391·2	2		,,	,,	41808
2389·5	4		,,	,,	41838
2388·8	6		,,	,,	41850
2386·7	4		,,	,,	41887
2386·4	4		,,	,,	41892
2385·6	2		,,	,,	41906
2384·0	2		,,	,,	41934
2383·4	5		,,	,,	41945
2383·1	2		,,	12·5	41950
2382·3	4		,,	,,	41964
2381·9	2		,,	,,	41971
2381·7	5		,,	,,	41975
2381·0	2		,,	,,	41987
2380·5	2		,,	,,	41996
2378·60	7		,,	,,	42032·6
2377·1	2n		,,	,,	42056
2376·9	2		,,	,,	42060
2375·2	4		,,	,,	42090
2373·7	2		0·70	,,	42116

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2373·4	2		0·70	12·5	42122
2373·1	2		„	„	42127
2372·5	2		„	„	42138
2371·9	4		„	„	42148
2371·6	2		„	„	42154
2370·7	4		„	„	42170
2369·7	2		„	„	42187
2367·4	2b		„	12·6	42227
2367·2	2		„	„	42231
2366·7	2		„	„	42240
2365·6	2n		„	„	42260
2365·2	2		„	„	42267
2365·0	2		„	„	42270
2363·82	7		„	„	42291·8
2362·6	2		„	„	42313
2362·3	2		„	„	42319
2361·6	4		„	„	42331
2361·1	2		„	„	42340
2360·7	4		„	„	42347
2360·4	4		„	„	42353
2359·0	2		„	„	42378
2358·2	4		„	„	42392
2356·6	2		„	„	42421
2356·5	2		„	„	42423
2355·6	2		„	„	42439
2355·0	2		„	„	42450
2354·5	2		„	12·7	42459
2353·4	5		„	„	42479
2352 2	2		„	„	42500
2351·9	4		„	„	42506
2351·2	4		„	„	42518
2348·4	2b		„	„	42569
2347·8	4		„	„	42580
2347·4	4		„	„	42587
2347·2	2		„	„	42591
2346·6	4		„	„	42602
2345·5	4		„	„	42622
2345·4	2		„	„	42624
2344·7	4		„	„	42636
2344·3	4		„	„	42644
2343·6	2		„	„	42656
2342·4	2		„	„	42678
2341·2	4		„	„	42700
2340·3	2		„	12·8	42717
2339·5	2		„	„	42731
2339·0	4		„	„	42740
2338·7	2		„	„	42746
2338·0	4		„	„	42759
2337·5	2		„	„	42768
2337·1	2		„	„	42775
2336·3	4		„	„	42790
2334·8	2		„	„	42817
2334·2	4		„	„	42828
2333·6	2		„	„	42839
2333·1	2		„	„	42848

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2330·4	4		0·70	12·8	42898
2329·2	4		,,	,,	42920
2327·7	4		,,	,,	42948
2327·2	2		,,	12·9	42957
2326·5	4		,,	,,	42970
2326·1	4		,,	,,	42977
2324·3	4		0·69	,,	43011
2320·5	2		,,	,,	43081
2319·9	2		,,	,,	43092
2318·4	2		,,	,,	43120
2318·2	2		,,	,,	43124
2317·1	4		,,	,,	43144
2316·1	2		,,	,,	43163
2314·2	4		,,	13·0	43198
2313·7	2		,,	,,	43208
2312·6	2		,,	,,	43228
2311·6	4		,,	,,	43247
2309·3	2		,,	,,	43290
2309·0	2		,,	,,	43296
2307·7	4		,,	,,	43320
2307·5	2		,,	,,	43324
2306·1	2n		,,	,,	43350
2305·1	2		,,	,,	43369
2304·1	2		,,	,,	43388
2303·0	2		,,	,,	43409
2302·5	2		,,	,,	43418
2302·0	2		,,	,,	43427
2301·4	4		,,	,,	43439
2300·2	2		,,	13·1	43461
2299·9	2		,,	,,	43467
2298·9	2		,,	,,	43486
2297·3	2		,,	,,	43516
2296·7	2		,,	,,	43528
2296·0	2		,,	,,	43541
2295·2	2		,,	,,	43556
2293·5	2		,,	,,	43588
2293·4	4		,,	,,	43590
2292·1	4		,,	,,	43615
2291·5	2		,,	,,	43627
2290·5	2		,,	,,	43646
2287·9	2		,,	13·2	43695
2287·8	2		,,	,,	43697
2287·2	2		,,	,,	43709
2286·3	5		,,	,,	43726
2283·6	2		,,	,,	43778
2282·5	2		,,	,,	43799
2282·0	4		,,	,,	43808
2281·2	2		,,	,,	43824
2280·6	2n		,,	,,	43835
2278·9	2		,,	,,	43868
2278·7	2		,,	,,	43872
2277·4	2		0·68	,,	43897
2277·0	2		,,	,,	43904
2276·6	2		,,	,,	43912
2276·3	2		,,	,,	43918

COBALT—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2275·8	2		0·68	13·3	43928
2275·5	2		„	„	43933
2273·3	2n		„	„	43976
2272·4	2		„	„	43993
2271·4	2		„	„	44013
2270·4	2		„	„	44032
2269·8	2		„	„	44044
2268·3	2		„	„	44073
2266·5	4		„	„	44108
2264·6	2		„	„	44145
*2261·7	2		„	13·4	44202
2260·1	4		„	„	44233
2256·7	4		„	„	44299
2256·1	2		„	„	44311
2253·5	4		„	„	44362
2252·3	2b		„	„	44386
2251·2	2n		„	„	44408
2250·5	2n		„	13·5	44422
2250·1	2n		„	„	44429
2248·7	2		„	„	44457
2248·2	2		„	„	44467
2246·9	2		„	„	44493
2246·2	2n		„	„	44507
2245·2	4		„	„	44526
2242·8	2		„	„	44574
2242·6	2		„	„	44578
2237·1	2		„	13·6	44687
2232·1	4		„	„	44787
2230·5	4n		„	„	44819
2229·1	2		0·67	„	44847
2225·0	2		„	13·7	44930
2220·3	4b		„	„	45025
2213·9	4		„	13·8	45155
2211·5	2		„	„	45204
2206·3	4		„	„	45311
2205·9	2		„	„	45319
2205·6	2		„	„	45325
2205·2	2		„	„	45333
2203·0	2		„	13·9	45379
2193·7	4		„	„	45571
2192·6	2		„	„	45594
2192·3	2		„	14·0	45600
2190·9	2		„	„	45629
2190·7	4		„	„	45634

Nickel.

Hasselberg, 'Kongl. Svenska Vetenskaps-Akadem. Handl.' Bd. 28, No. 6, 1896.
Exner and Haschek, 'Sitzber. kaiserl. Akad. Wissensch. Wien,' cv. (2), 1896.

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
*5893·13	5	5893·22 Thalén	1·61	4·6	16964·3
*5858·03	4	5857·72 "	1·60	"	17066·0
*5847·26	2		1·59	"	17097·4
*5805·45	4		1·58	4·7	17220·5
*5796·35	2		"	"	17247·5
*5761·10	5		1·57	"	17353·1
*5754·86	6		"	"	17371·9
*5748·57	3		"	"	17390·9
*5715·31	6		1·56	4·8	17492·1
*5712·10	6		"	"	17501·9
*5709·80	7		"	"	17508·9
*5695·22	6n		1·55	"	17553·8
*5682·44	7n		"	"	17593·3
*5670·22	4		"	"	17631·2
*5664·28	5		1·54	"	17649·7
*5649·90	5		"	"	17694·6
*5643·31	3n		"	"	17715·3
*5642·08	3		"	"	17719·2
5639·02	3		"	"	17728·8
*5637·32	4		"	"	17734·1
*5628·62	3		"	"	17761·5
*5625·56	6		1·53	"	17771·2
*5615·00	6s		"	"	17804·6
*5600·29	4		"	4·9	17851·3
*5594·00	6		"	"	17871·4
*5592·44†	7s		"	"	17876·4
*5589·63	4n		1·52	"	17885·4
*5588·12	5s		"	"	17890·2
*5578·98	5		"	"	17919·5
*5553·97	4s		"	"	18000·2
*5510·28	5s		1·50	"	18143·0
5504·50	3		"	"	18162·1
*5495·20	3s		"	5·0	18192·7
*5477·13	10	5477·20 "	"	"	18252·7
*5468·42	2		1·49	"	18281·8
*5462·71	4		"	"	18300·9
*5436·10	5s		1·48	"	18390·5
*5424·85	4		"	"	18428·7
*5411·50	4s		"	"	18474·2
*5392·68	2		1·47	5·1	18538·6
*5388·71	2		"	"	18552·2
*5371·64	5		"	"	18611·2
*5268·59	2		1·44	"	18975·1
*5220·51	2		1·43	"	19149·9
*5216·72	2		"	"	19163·8
*5197·40	2		1·42	5·3	19235·1
5192·70	2		"	"	19252·5

* Coincident with a solar line.
† Solar line double; least refrangible component due to Nickel.
‡ Observed also by Exner and Haschek in the Spark spectrum.

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
*5186·80	2		1·42	5·3	19274·4
*5184·78	3		,,	,,	19281·9
*5176·73	4	5176·71 Thalén	,,	,,	19311·9
*5168·83	5	5169·41 ,,	1·41	,,	19341·4
*5158·20	2		,,	,,	19381·3
*5155·92	7n	5156·21 ,,	,,	,,	19389·9
*5155·34	4n		,,	,,	19392·1
*5153·43	4		,,	,,	19399·3
*5146·64	8n	5146·81 ,,	,,	,,	19424·9
*5142·96	7n	5143·11 ,,	,,	,,	19438·8
*5137·23	8s	5137·91 ,,	1·40	,,	19460·4
*5131·94	3n		,,	,,	19480·5
*5130·55	2		,,	,,	19485·8
*5129·52	6		,,	,,	19489·7
*5125·39§	5		,,	,,	19505·4
5121·74	3		,,	,,	19519·3
*5115·55	8s	5116·00 ,,	,,	5·4	19542·8
*5103·13	4		,,	,,	19590·4
*5100·13	7n	5100·66 ,,	1·39	,,	19601·9
*5099·50	5s	5099·46 ,,	,,	,,	19604·4
*5097·06	4n		,,	,,	19613·7
*5094·61	2		,,	,,	19623·2
*5089·13	2		,,	,,	19644·3
*5088·74	2		,,	,,	19645·8
*5084·27	8n		,,	,,	19663·1
*5082·55	5n		,,	,,	19669·8
*5081·30	10n	5081·56 ,,	,,	,,	19674·6
*5080·70	10	5080·70 ,,	,,	,,	19676·9
*5080·16	3		,,	,,	19679·0
*5058·22	2		1·38	,,	19664·4
*5051·74§	2n		,,	,,	19689·8
*5049·01†	5n		,,	,,	19700·5
*5042·35	5n		,,	,,	19726·6
*5038·80	4		,,	,,	19740·6
*5035·55	10	5035·56 ,,	,,	,,	19753·4
*5018·50	4n		1·37	5·5	19920·8
*5017·75	7	5017·46 ,,	,,	,,	19923·8
*5012·62	4s		,,	,,	19944·1
*5011·11	3n		,,	,,	19950·2
*5010·22	2		,,	,,	19953·7
*5003·92	2		,,	,,	19978·8
*5000·48§	5n		,,	,,	19992·6
*4998·42	4		,,	,,	20000·8
*4997·04	2n		,,	,,	20006·3
*4984·30	7	4984·10 ,,	1·36	,,	20057·6
*4980·36	7	4980·40 ,,	,,	,,	20073·4
*4976·54	2		,,	,,	20088·8
*4971·54	3		,,	,,	20109·0
*4953·34	3		1·35	,,	20182·9

§ Solar line double { 5051·75, 5051·85.

† Not coincident with Chromium, 5048·96.

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ −	Oscillation Frequency in Vacuo
*4946·20	2		1·35	5·5	20212·0
*4945·63	3n		,,	,,	20214·4
*4937·51	4n		,,	5·6	20247·5
*4936·02	4s	4935·90 Thalén	,,	,,	20253·6
*4925·74	3		,,	,,	20295·9
*4918·86	2		,,	,,	20324·3
*4918·53	5s	4918·40 ,,	,,	,,	20325·7
*4914·15	4n		1·34	,,	20343·8
*4912·22	3n		,,	,,	20351·8
*4904·56	7	4904·70 ,,	,,	,,	20383·6
*4887·16	3		,,	,,	20456·2
*4874·95	2		1·33	,,	20507·4
*4873·60	4	4873·80 ,,	,,	,,	20513·1
*4870·97†	4		,,	,,	20524·2
*4866·42	7	4866·20 ,,	,,	,,	20543·4
*4864·46	2n		,,	,,	20551·7
*4864·11	3n		,,	,,	20553·1
*4857·57	3		,,	5·7	20580·7
*4855·57	6	4855·60 ,,	,,	,,	20589·2
*4852·70	3n		,,	,,	20601·4
*4843·27	2		,,	,,	20641·5
*4838·80	4		1·32	,,	20660·6
*4832·86	3		,,	,,	20686·0
*4831·30	5	4831·10 ,,	,,	,,	20692·7
*4829·18	6	4829·30 ,,	,,	,,	20701·7
*4821·29	2		,,	,,	20736·0
*4817·97	2		,,	,,	20749·9
*4814·77	2		,,	,,	20763·7
*4812·15	2		,,	,,	20775·0
*4809·05	2		,,	,,	20788·4
*4807·17	4		,,	,,	20796·6
*4792·98	2		1·31	,,	20858·1
*4786·66	6	4786·64 ,,	,,	,,	20885·7
*4786·42	2		,,	,,	20886·7
*4773·55	2		,,	5·8	20943·0
*4764·07	4		1·30	,,	20984·7
*4762·78	3		,,	,,	20990·3
*4756·70	6	4755·84 ,,	,,	,,	21017·2
*4754·95	3		,,	,,	21024·9
*4752·58	4		,,	,,	21035·4
*4752·30	3		,,	,,	21036·6
*4732·66	4		,,	,,	21124·0
*4732·00	4		,,	,,	21126·9
*4729·50	2		1·29	,,	21138·1
*4728·06	2		,,	,,	21144·5
‡*4715·93	6		,,	,,	21198·9
‡*4714·59	9	4714·54 ,,	,,	,,	21205·0
*4712·24	2		,,	,,	21215·5
‡*4703·96	5n		,,	5·9	21252·8
‡*4701·72	4		,,	,,	21262·9
‡*4701·52	2		,,	,,	21263·8
‡*4686·39†	5s		1·28	,,	21332·5
*4675·80	2		,,	,,	21380·8

† Not coincident with Chromium, 4870·96, 4686·38.

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	1/λ −	
‡*4667·96	4		1·28	5·9	21416·7
‡*4667·16	3		”	”	21420·4
*4655·85	2		”	”	21472·5
‡*4648·82	6	4647·88 Thalén	1·27	”	21504·9
*4647·47	3		”	”	21511·2
*4618·22§	3		”	6·0	21647·4
*4614·85	2		1·26	”	21663·2
‡*4606·37	5		”	”	21703·1
‡*4605·15	8		”	”	21708·8
‡*4600·51	6		”	”	21730·7
‡4596·11	4n		”	”	21751·5
‡*4595·07	4		”	”	21756·5
‡*4592·69§	7		”	”	21767·7
*4580·77	3		1·25	”	21824·4
4567·59	2		”	”	21887·4
*4560·10	4		”	6·1	21923·2
*4553·37	3		”	”	21955·7
‡*4551·45	4		”	”	21964·9
‡*4547·44	5		”	”	21984·3
‡*4547·14§	4		”	”	21985·7
‡*4520·20	5s		1·24	”	22116·8
‡*4513·20	4		”	”	22151·1
4506·53	2		”	”	22183·9
*4490·71	4n		1·23	6·2	22262·0
*4481·30	2n		”	”	22308·8
‡*4470·61	8		”	”	22362·1
‡*4466·54	4		1·22	”	22382·5
‡*4463·57	4		”	”	22397·4
‡*4462·59	8		”	”	22402·3
‡*4459·21§	9		”	”	22419·3
4450·44	2		”	”	22463·5
4450·29	2		”	”	22464·2
‡4442·61	4		”	”	22503·1
4441·64	2		”	”	22508·0
‡4437·75	4		”	”	22527·7
‡*4437·17	5		”	”	22530·4
4423·24	3		1·21	6·3	22601·6
‡*4410·70	5n		”	”	22665·8
‡*4401·70§	9		”	”	22712·2
*4401·02	4		”	”	22715·7
*4399·75	4		”	”	22722·3
‡*4398·78	2		”	”	22727·3
4390·47	3n		1·20	”	22770·3
‡*4390·00	4		”	”	22772·7
‡4386·62	3n		”	”	22790·3
‡*4384·68	5		”	”	22800·4
4383·05	2		”	”	22808·9
*4370·21	3n		”	”	22875·9
‡*4368·45	4		”	6·4	22885·0
‡*4359·73‖	6s		”	”	22930·8

§ Solar line double { 4618·22 Ni / 4618·15 } { 4592·70 Ni / 4592·80 Fe } { 4547·15 Ni / 4547·25 Fe } { 4459·20 Ni / 4459·30 Fe } { 4401·70 Ni. / 4401·60 }

‖ Solar line triple { 4359·80 Ba. / 4359·78 Cr. / 4359·73 Ni. }

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
‡*4356·07	4n		1·19	6·4	22950·1
‡4331·78	6		,,	,,	23078·8
*4330 85	5		,,	,,	23083·8
*4325·75	5s		,,	,,	23111·0
*4325·49	3n		,,	,,	23112·4
*4307·40	3		1·18	6·5	23209·4
*4298·94	2		,,	,,	23255·0
‡*4298·68	3		,,	,,	23256·5
*4297·15	2		,,	,,	23264·7
‡*4296·06	6		,,	,,	23270·6
‡*4288·16§	7		,,	,,	23313·5
‡*4284·83	5		,,	,,	23331·6
*4252·25	2		1·17	6·6	23510·4
4236·55	3		1·16	,,	23597·5
‡4231·23	4		,,	,,	23627·2
4221·87	2		,,	,,	23679·6
4202·33	2		1·15	,,	23789·7
‡*4201·88	5s		,,	,,	23792·3
‡*4200·61	4s		,,	,,	23799·5
‡*4195·71§	5		,,	6·7	23827·2
‡4184·65	3		,,	,,	23890·2
‡4167·16	3n		,,	,,	23990·5
‡*4164·82	2s		1·14	,,	24003·9
‡*4150·55	3		,,	,,	24086·5
*4143·12	2		,,	6·8	24129·6
*4142·47	4		,,	,,	24133·4
*4142·34	2		,,	,,	24134·1
‡4138·67	2		,,	,,	24155·6
4123·96	2		1·13	,,	24241·7
‡*4121·48	6s		,,	,,	24256·3
‡*4116·14	4		,,	,,	24287·8
4104·37	2		,,	,,	24357·5
‡*4086·30	2		1·12	6·9	24465·1
4075·75	3n		,,	,,	24528·5
4075·05	3s		,,	,,	24532·7
4073·08	2		,,	,,	24544·5
4069·39	2		,,	,,	24566·8
4064·55	4		,,	,,	24596·1
‡4057·45	2		,,	,,	24639·1
4046·91	2		1·11	7·0	24703·2
*4025·26	3		,,	,,	24836·1
‡4022·20	2		,,	,,	24855·0
‡*4019·20	3		,,	,,	24873·6
‡4017·65	4n		,,	,,	24883·2
‡4010·14	3		1·10	,,	24929·8
‡*4006·30	4		,,	,,	24953·7
*3995·45	7		,,	7·1	25021·4
3994·13	4n		,,	,,	25029·5
‡3984·18	4n		,,	,,	25092·1
‡3974·83	4n		1·09	,,	25151·2
‡*3973·70§	8		,,	,,	25158·4

§ Solar line double { 4288·15 / 4288·05 } { 4195·77 Fe / 4195·71 Ni } { 3973·81 Fe. / 3973·70 Ni. }

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
‡*3972·31	5		1·09	7·1	25167·2
‡3970·65	4n		,,	,,	25177·7
3954·61	3n		,,	7·2	25279·7
‡3944·25	7n		,,	,,	25346·2
‡3914·65	2		1·08	,,	25537·9
‡*3913·12	4		,,	,,	25547·9
*3912·44	3n		,,	,,	25552·3
*3909·10	3n		,,	7·3	25574·0
‡*3905·67	3		,,	,,	25596·5
‡*3889·80	5s		1·07	,,	25701·0
‡*3871·73	3		,,	,,	25821·0
‡*3863·21	5		,,	,,	25880·0
*3858·40‡‡	9r	3858·42 L. & D.	,,	,,	25910·2
‡*3844·71	3		1·06	,,	26002·5
*3844·40	3n		,,	,,	26004·6
‡*3833·02	4		,,	,,	26081·8
‡*3832·44	5	3832·32	,,	,,	26085·7
‡*3831·82	6		,,	,,	26090·0
3829·49	5		,,	,,	26105·8
‡*3811·46§	2		1·05	7·4	26229·3
*3807·30‡‡	8	3807·22	,,	,,	26257·9
‡*3793·75	6s		,,	,,	26351·7
‡*3792·48	5s		,,	,,	26360·6
*3783·67‡‡	8	3783·62	,,	,,	26422·0
*3778·22	3		,,	,,	26460·1
*3775·71‡‡	9	3775·62	1·04	,,	26477·7
‡*3772·70	5s		,,	7·5	26498·7
*3769·58‡‡	2	3769·50	,,	,,	26520·7
‡*3762·76	4		,,	,,	26568·7
‡*3749·15§	4s		,,	,,	26665·2
‡*3744·68	5s		,,	,,	26697·1
‡*3739·89	2		,,	,,	26731·3
‡*3739·36†	5		,,	,,	26735·0
‡*3736·94	7s	3736·70 ,,	1·03	,,	26752·4
‡*3730·88	3		,,	,,	26795·8
‡*3729·05	2		,,	,,	26809·0
‡*3724·95	3	3724·80 ,,	,,	7·6	26838·4
‡*3722·63	6		,,	,,	26855·1
‡*3715·61	3		,,	,,	26905·9
*3713·87	2		,,	,,	26918·5
*3713·49	2		,,	,,	26921·2
‡*3697·04	2		,,	,,	27041·1
‡*3694·10§	4		1·02	,,	27062·6
‡*3688·58	5s	3688·19 ,,	,,	,,	27103·1
3683·65	2		,,	7·7	27139·3
‡*3674·28§	7s	3673·99 ,,	,,	,,	27208·5
‡*3670·57	5s	3670·29 ,,	,,	,,	27236·0

§ Solar line double $\begin{cases}3811·56 \text{ Ti}\\3811·46 \text{ Ni}\end{cases}$ $\begin{cases}3694·20 \text{ Fe}\\3694·10 \text{ Ni}\end{cases}$ $\begin{cases}3674·28 \text{ Ni.}\\3674·18 \text{ Fe.}\end{cases}$

† Solar line triple $\begin{cases}3739·46 \text{ Fe.}\\3739·36 \text{ Ni.}\\3739·26 \text{ Fe.}\end{cases}$

‡‡ Exner and Haschek's numbers: 3858·49, 3807·28, 3783·64, 3775·71, 3769·63.

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
‡*3669·38§	4s		1·02	7·7	27244·9
‡*3668·35	2		"	"	27252·5
‡*3664·24††	6s	3663·99 L. & D.	"	"	27283·1
‡*3662·10	4s		"	"	27299·0
‡3644·13	2		1·01	"	27433·7
‡3642·58	2		"	"	27445·4
‡*3641·78	3		"	"	27451·4
‡*3635·10	4s	3635·49 "	"	7·8	27501·8
‡*3630·04	3		"	"	27540·1
‡*3624·87§	6s	3624·68 "	"	"	27579·4
*3619·52‡‡	10nr	3619·38 "	"	"	27620·2
‡*3612·86	7	3612·68 "	1·00	"	27671·1
‡*3611·58	2		"	"	27680·9
*3610·60‡‡	4r	3610·38 "	"	"	27688·4
‡*3609·44	5		"	"	27697·3
‡*3607·02	2		"	"	27715·9
‡*3602·41	5		"	"	27751·4
*3597·84‡‡	7n	3597·58 "	"	"	27786·7
‡*3588·08	5s		"	7·9	27862·2
*3577·37	2		0·99	"	27945·6
*3571·99‡‡	7nr	3571·78 "	"	"	27987·7
*3566·50‡‡	9nr	3566·27 "	"	"	28030·8
‡*3561·91	4s	3561·67 "	"	"	28073·3
‡*3560·08	2		"	"	28081·4
‡*3553·63	4	3553·37 "	"	"	28132·3
*3551·66	5	3551·37 "	"	8·0	28147·8
‡*3548·34§§	5	3548·07 "	"	"	28174·2
*3533·89	2n		0·98	"	28289·4
‡*3530·73	3	3530·47 "	"	"	28314·8
‡*3529·76	2		"	"	28322·5
‡*3529·03	3		"	"	28328·4
‡*3528·13	5		"	"	28335·6
*3524·65‡‡	10nr	3524·46 "	"	"	28363·6
*3523·19	3		"	"	28375·4
*3519·90‡‡	6	3519·66 "	"	"	28401·9
‡*3518·80	4	3518·56 "	"	"	28410·8
‡*3516·35	4		"	"	28430·6
*3515·17‡‡	9nr	3514·96 "	"	"	28440·1
*3514·06‡‡	5		"	"	28449·1
*3510·47‡‡	8nr	3510·26 "	"	8·1	28478·1
‡*3507·85	4s	3507·86 "	"	"	28499·4
‡*3502·76	4		"	"	28540·8
*3501·00‡‡	6	3500·55 "	"	"	28555·2
‡*3496·50	2		0·97	"	28591·9
*3493·10‡‡	9nr	3492·85 "	"	"	28619·8
‡*3486·04	5	3485·75 "	"	"	28677·7

§ Solar line double { 3973·81 Fe / 3973·70 Ni } { 3811·56 Ti / 3811·46 Ni } { 3694·20 Fe / 3694·10 Ni } { 3674·28 Ni / 3674·18 Fe } { 3669·37 Ni. / 3669·30 Fe. }

‡‡ Exner and Haschek's numbers: 3619·52, 3610·55, 3597·78, 3571·96, 3566·50, 3524·60, 3519·90, 3515·15, 3514·10, 3510·45, 3501·00, 3493·15.

§§ Also Manganese.

NICKEL—*continued.*

Hasselberg Wave-length (Rowland) Arc Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
‡*3480·36	2		0·97	8·1	28724·6
‡*3479·43	2		„	„	28732·2
‡*3478·48	2		„	„	28740·1
*3472·68‡‡	7nr	3472·45 L & D.	„	„	28788·1
‡*3469·64	5s	3469·45 „	„	8·2	28813·2
‡*3467·63	5s	3467·35 „	„	„	28829·9
‡*3462·95†	2		„	„	28872·7
*3461·78‡‡	8nr	3461·66 „	„	„	28878·7
*3458·59‡‡	8nr	3458·45 „	0·96	„	28883·3

SPARK SPECTRUM.

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3458·51	8		0·96	8·2	28906·0
3454·2	4		„	„	28942
3453·5	5		„	„	28948
3452·92	7		„	„	28952·8
3450·6	2		„	„	28972
3449·5	4		„	„	28982
3449·2	4		„	„	28984
3448·5	2		„	„	28990
3446·34	8		„	„	29008·1
3444·4	2		„	„	29025
3444·0	2		„	„	29028
3443·0	2		„	„	29036
3442·6	2		„	„	29042
3439·0	2n		„	„	29070
3435·6	2		„	„	29099
3433·65	7		„	„	29115·3
3427·8	2		„	8·3	29165
3426·3	2		„	„	29178
3423·76	7		„	„	29199·4
3422·8	2		„	„	29208
3422·4	2		„	„	29211
3421·4	4		„	„	29220
3420·8	2		„	„	29225
3414·83	8		0·95	„	29275·7
3414·0	4		„	„	29283
3413·5	5		„	„	29287
3412·6	2		„	„	29295
3412·1	2n		„	„	29299
3411·1	2n		„	„	29308
3409·5	4		„	„	29322
3409·1	4		„	„	29325

‡‡ Exner and Haschek's numbers: 3472·59, 3461·72, 3458·51.
† Probably due to Cobalt.

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3407·4	5		0·95	8·3	29340
3403·5	5		,,	,,	29374
3401·8	2		,,	,,	29388
3401·3	4		,,	,,	29393
3396·3	2		,,	8·4	29436
3393·05	7		,,	,,	29463·6
3391·2	6		,,	,,	29480
3385·7	2		,,	,,	29528
3381·1	5		,,	,,	29568
3380·62	7		,,	,,	29572·0
3376·4	2		0·94	,,	29609
3374·8	5		,,	,,	29623
3374·4	5		,,	,,	29627
3374·1	5		,,	,,	29630
3372·1	6		,,	,,	29647
3369·66	7		,,	,,	29668·2
3367·9	2		,,	,,	29684
3366·9	4		,,	,,	29693
3366·3	6		,,	,,	29698
3365·9	6		,,	,,	29702
3364·7	2		,,	,,	29712
3364·0	2		,,	,,	29719
3363·8	2		,,	,,	29720
3362·9	2		,,	,,	29728
3361·7	5		,,	,,	29739
3359·3	4		,,	8·5	29760
3350·5	4		,,	,,	29838
3345·1	2		,,	,,	29886
3339·1	2n		,,	,,	29940
3336·1	2b		0·93	,,	29967
3327·5	2		,,	,,	30045
3327·0	2		,,	,,	30049
3322·4	6		,,	8·6	30090
3320·9	2		,,	,,	30103
3320·3	6		,,	,,	30109
3315·7	6		,,	,,	30151
3313·1	2		,,	,,	30174
3312·3	4		,,	,,	30182
3310·2	2		,,	,,	30201
3309·5	2		,,	,,	30207
3306·9	2		,,	,,	30231
3305·0	2		,,	,,	30248
3302·6	2n		,,	,,	30270
3301·8	2n		,,	,,	30278
3299·2	2b		0·92	,,	30301
3296·3	2		,,	,,	30328
3293·8	2		,,	,,	30351
3290·7	2		,,	,,	30380
3288·5	2b		,,	8·7	30400
3287·1	4		,,	,,	30413
3286·0	2n		,,	,,	30423
3285·1	2		,,	,,	30431
3284·5	2		,,	,,	30437
3282·8	5		,,	,,	30453
3281·9	4		,,	,,	30461

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3280·7	2		0·92	8·7	30472
3276·7	2b		,,	,,	30510
3275·0	2		,,	,,	30525
3274·0	6		,,	,,	30535
3273·6	2n		,,	,,	30538
3271·2	5		,,	,,	30561
3269·0	2		,,	,,	30581
3268·2	2		,,	,,	30589
3261·9	2n		,,	,,	30648
3261·1	2n		,,	,,	30656
3259·0	2n		0·91	,,	30675
3256·1	2		,,	,,	30703
3250·8	6		,,	8 8	30753
3249·5	4		,,	,,	30765
3248·6	5		,,	,,	30773
3247·72	7		,,	,,	30782·0
3245·5	2n		,,	,,	30803
3243·22	7		,,	,,	30824·8
3242·0	2		,,	,,	30876
3237·1	2		,,	,,	30883
3236·4	2n		,,	,,	30890
3235·8	2		,,	,,	30895
3234·8	6		,,	,,	30905
3234·0	2		,,	,,	30912
3233·11	7		,,	,,	30921·2
3231·6	2		,,	,,	30935
3227·2	4		,,	,,	30978
3225·2	6		,,	,,	30997
3224·0	2		,,	,,	31008
3223·7	4		,,	,,	31011
3221·8	5		,,	,,	31030
3221·4	5		,,	,,	31033
3220·2	2		0·90	,,	31045
3220·0	2		,,	,,	31047
3219·5	2		,,	,,	31052
3217·93	7		,,	,,	31067·1
3216·9	4		,,	,,	31077
3215·7	2n		,,	8·9	31088
3214·1	6		,,	,,	31104
3213·5	4		,,	,,	31110
3212·5	2		,,	,,	31119
3210·1	4		,,	,,	31143
3209·1	2		,,	,,	31152
3207·1	2		,,	,,	31172
3205·4	2		,,	,,	31188
3204·7	2		,,	,,	31195
3202·3	5		,,	,,	31219
3200·6	4		,,	,,	31235
3199·5	2		,,	,,	31246
3197·3	5		,,	,,	31267
3195·7	4		,,	,,	31283
3195·4	2		,,	,,	31286
3195·1	2		,,	,,	31289
3192·2	2b		,,	,,	31317
3191·3	2		,,	,,	31326

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3189·9	2n		0·90	8·9	31340
3187·8	2n		,,	,,	31361
3186·7	2n		,,	,,	31371
3186·3	2		,,	,,	31375
3184·5	4		,,	,,	31393
3183·4	2		,,	,,	31404
3183·2	2		,,	,,	31406
3181·9	4		0·89	,,	31419
3179·7	2n		,,	9·0	31441
3179·0	2n		,,	,,	31447
3177·5	2		,,	,,	31462
3177·0	2		,,	,,	31467
3176·4	2		,,	,,	31473
3174·2	2n		,,	,,	31495
3170·8	2		,,	,,	31529
3166·5	2		,,	,,	31572
3165·6	2		,,	,,	31581
3165·0	2		,,	,,	31587
3164·4	2		,,	,,	31593
3159·7	2		,,	,,	31640
3154·8	2		,,	,,	31689
3153·5	2n		,,	,,	31702
3153·0	2		,,	,,	31707
3151·5	2n		,,	,,	31722
3149·5	2		,,	,,	31742
3146·4	2		,,	9·1	31773
3145·8	4		,,	,,	31779
3145·3	2		,,	,,	31784
3134·26	8		0·88	,,	31896·4
3133·0	2b		,,	,,	31909
3129·5	4		,,	,,	31945
3127·8	2n		,,	,,	31962
3127·3	2n		,,	,,	31967
3121·7	2n		,,	,,	32025
3121·0	2b		,,	,,	32032
3116·8	2		,,	,,	32075
3114·3	6		,,	9·2	32101
3107·8	2		,,	,,	32168
3105·6	4		,,	,,	32191
3102·00	8		,,	,,	32228·1
3101·61	8		0·87	,,	32232·1
3099·2	6		,,	,,	32257
3097·2	5		,,	,,	32278
3094·4	2		,,	,,	32307
3089·9	2		,,	,,	32355
3088·3	2n		,,	,,	32371
3087·2	6		,,	,,	32383
3080·82	7		,,	9·3	32449·6
3066·6	2		,,	,,	32600
3064·75	7		,,	,,	32619·8
3064·1	2		,,	,,	32627
3057·72	8		0·86	,,	32694·8
3054·40	7		,,	,,	32730·4
3050·88	8		,,	9·4	32768·0
3047·2	2		,,	,,	32808

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3045·1	5		0·86	9·4	32831
3038·05	7		"	"	32906·4
3035·5	2		"	"	32935
3032·6	2		"	"	32966
3032·0	5		"	"	32973
3031·3	2		"	"	32980
3029·5	2		"	"	33000
3026·0	2		"	"	33038
3024·2	2		"	9·5	33058
3020·0	2		0·85	"	33104
3019·3	6		"	"	33111
3012·10	8		"	"	33189·9
3008·2	2		"	"	33233
3003·73	8		"	"	33282·4
3002·60	8		"	"	33295·0
3092·66	7		"	9·6	33405·5
3091·3	2		"	"	33420
3088·1	4		"	"	33456
3087·3	2		"	"	33465
3085·8	2		"	"	33482
3085·0	2		"	"	33491
3084·3	5		"	"	33499
3083·6	4		"	"	33507
3081·8	6		0·84	"	33527
3076·8	2		"	"	33583
3073·8	2		"	"	33617
3065·5	2b		"	9·7	33711
3061·5	2		"	"	33757
3058·5	2		"	"	33791
3055·2	2b		"	"	33829
3047·6	4		"	"	33916
3044·1	6		"	9·8	33956
3042·9	2		0·83	"	33970
3034·8	2n		"	"	34064
3022·3	2n		"	"	34210
2921·3	2b		"	9·9	34221
2919·2	2b		"	"	34246
2917·1	2b		"	"	34271
2914·2	2		"	"	34305
2913·7	6		"	"	34311
2912·3	2		"	"	34327
2907·6	4		"	"	34383
2906·0	2n		"	"	34402
2900·3	2n		0·82	"	34469
2897·2	2n		"	"	34506
2892·5	2n		"	10·0	34562
2891·4	2n		"	"	34575
2883·8	2b		"	"	34666
2882·5	2b		"	"	34682
2881·6	2		"	"	34693
2881·3	2n		"	"	34697
2873·3	2		"	"	34793
2870·0	2		"	10·1	34833
2868·7	2		"	"	34849
2865·5	2		"	"	34888

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2864·2	2n		0·81	10·1	34904
2863·7	6		,,	,,	34910
2861·6	2b		,,	,,	34935
2858·2	2		,,	,,	34977
2857·5	2b		,,	,,	34986
2855·6	2		,,	,,	35009
2853·6	2b		,,	,,	35033
2852·2	4		,,	,,	35051
2851·1	2b		,,	,,	35064
2849·8	2b		,,	,,	35080
2846·0	2n		,,	10·2	35127
2843·8	2b		,,	,,	35154
2842·5	5		,,	,,	35170
2840·7	2n		,,	,,	35193
2839·0	2		,,	,,	35214
2837·3	2n		,,	,,	35235
2836·6	2b		,,	,,	35243
2835·6	2		,,	,,	35256
2835·2	2b		,,	,,	35261
2834·6	2		,,	,,	35268
2832·4	2		,,	,,	35296
2831·6	2		,,	,,	35306
2829·2	2		,,	,,	35336
2825·3	4		,,	,,	35384
2823·9	2n		0·80	10·3	35402
2823·3	2		,,	,,	35410
2821·3	4		,,	,,	35435
2816·4	2n		,,	,,	35496
2815·6	2n		,,	,,	35506
2814·3	2		,,	,,	35523
2813·3	2n		,,	,,	35535
2812·3	2n		,,	,,	35548
2810·3	2b		,,	,,	35573
2808·3	2		,,	,,	35599
2807·6	2n		,,	,,	35608
2805·7	4		,,	,,	35632
2804·8	2		,,	,,	35643
2802·74	7		,,	,,	35669·1
2802·3	2		,,	,,	35675
2801·2	2		,,	,,	35689
2800·9	2n		,,	,,	35693
2798·7	4		,,	10·4	35721
2798·3	2		,,	,,	35726
2798·1	2		,,	,,	35729
2795·59	7		,,	,,	35760·2
2794·9	4		,,	,,	35769
2790·8	2n		,,	,,	35822
2785·5	2b		,,	,,	35890
2779·8	2		0·79	,,	35964
2775·4	2b		,,	10·5	36021
2771·5	2n		,,	,,	36072
2770·2	2		,,	,,	36088
2769·0	2b		,,	,,	36104
2760·7	2		,,	,,	36213
2759·0	2b		,,	,,	36235

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2746·8	2		0·79	10·6	36395
2743·1	2		,,	,,	36444
2737·7	2		0·78	,,	36516
2735·5	2		,,	,,	36545
2725·0	2n		,,	10·7	36686
2723·7	2		,,	,,	36704
2722·9	2		,,	,,	36715
2722·4	2		,,	,,	36721
2721·2	2		,,	,,	36737
2711·9	2		,,	,,	36864
2710·7	2		,,	,,	36880
2710·4	2		,,	,,	36884
2708·8	2n		,,	,,	36906
2707·7	2		,,	,,	36921
2706·6	2		,,	,,	36936
2705·6	2		,,	,,	36949
2703·1	2		,,	10·8	36984
2700·4	2n		,,	,,	37021
2699·3	2n		,,	,,	37036
2696·6	2		0·77	,,	37073
2695·5	2		,,	,,	37088
2693·2	2		,,	,,	37120
2690·7	2b		,,	,,	37154
2689·8	2		,,	,,	37166
2684·5	4b		,,	,,	37240
2682·4	2b		,,	,,	37269
2680·4	2		,,	,,	37297
2679·2	2b		,,	10·9	37314
2674·8	2		,,	,,	37375
2674·5	2		,,	,,	37379
2673·3	2n		,,	,,	37396
2670·4	2		,,	,,	37437
2666·9	2n		,,	,,	37486
2666·1	2		,,	,,	37497
2665·9	2		,,	,,	37500
2665 3	4		,,	,,	37508
2659·6	2n		,,	,,	37589
2655·9	2n		,,	,,	37641
2655·4	2n		,,	,,	37648
2652·5	2b		0·76	11·0	37689
2650·8	2b		,,	,,	37713
2647·0	2b		,,	,,	37768
2642·0	2b		,,	,,	37839
2641·3	2b		,,	,,	37849
2639·8	2		,,	,,	37871
2639·5	2n		,,	,,	37875
2638·2	2		,,	,,	37894
2637·2	2b		,,	,,	37908
2633·0	2n		,,	,,	37968
2632·5	2n		,,	,,	37976
2631·6	2n		,,	11·1	37989
2631·5	4		,,	,,	37990
2631·2	4		,,	,,	37994
2630·4	4		,,	,,	38006
2629·7	2		,,	,,	38016

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2629·4	2		0·76	11·1	38020
2626·5	2b		,,	,,	38062
2623·1	2		,,	,,	38112
2622·1	2		,,	,,	38126
2618·9	2b		,,	,,	38173
2615·3	4b		,,	,,	38226
2613·9	2		,,	,,	38246
2611·7	2		,,	,,	38278
2610·7	2		,,	,,	38293
2610·2	4n		,,	,,	38300
2606·5	4b		0·75	11·2	38355
2605·7	4		,,	,,	38366
2603·9	2		,,	,,	38393
2603·6	2		,,	,,	38397
2602·8	2		,,	,,	38409
2601·2	4b		,,	,,	38433
2599·1	2		,,	,,	38464
2597·7	2		,,	,,	38485
2592·8	2		,,	,,	38557
2589·8	2		,,	,,	38602
2589·6	2		,,	,,	38605
2589·0	2		,,	,,	38614
2588·4	2		,,	11·3	38623
2588·1	2		,,	,,	38627
2587·6	2		,,	,,	38635
2584·1	4		,,	,,	38687
2583·4	2		,,	,,	38698
2578·5	2		,,	,,	38771
2571·0	2n		,,	,,	38884
2569·8	2n		,,	,,	38903
2566·2	4n		,,	11·4	38957
2563·8	2		0·74	,,	38994
2561·6	2		,,	,,	39027
2560·3	2n		,,	,,	39047
2558·7	2		,,	,,	39071
2558·0	2		,,	,,	39082
2556·8	2b		,,	,,	39100
2555·2	2n		,,	,,	39125
2553·0	2b		,,	,,	39159
2551·1	2		,,	,,	39188
2550·7	2		,,	,,	39194
2550·0	2		,,	,,	39205
2549·4	4		,,	,,	39214
2548·8	2		,,	11·5	39223
2547·5	2		,,	,,	39243
2547·3	2		,,	,,	39246
2546·00	7		,,	,,	39265·8
2543·5	2		,,	,,	39305
2541·3	2		,,	,,	39339
2540·8	2		,,	,,	39347
2540·3	2		,,	,,	39354
2539·2	4		,,	,,	39371
2536·1	2		,,	,,	39420
2535·7	2n		,,	,,	39426
2535·3	2n		,,	,,	39432

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2533·6	2		0·74	11·5	39459
2532·2	2		,,	,,	39480
2529·1	2		,,	11·6	39528
2528·1	2		,,	,,	39543
2527·6	2		,,	,,	39551
2524·3	2		,,	,,	39603
2522·9	2		,,	,,	39625
2521·7	2		,,	,,	39644
2521·4	2		,,	,,	39649
2521·2	2		,,	,,	39652
2519·3	2n		,,	,,	39682
2518·2	2		,,	,,	39699
2517·9	2		0·73	,,	39704
2516·2	2		,,	,,	39730
2514·7	2n		,,	,,	39754
2510·92	8		,,	11·7	39814·3
2506·8	2		,,	,,	39879
2505·8	5		,,	,,	39895
2492·1	2		,,	11·8	40115
2491·2	2		,,	,,	40129
2490·8	2		,,	,,	40136
2490·7	2		,,	,,	40137
2484·3	4n		,,	,,	40241
2483·3	2		,,	,,	40257
2482·7	2n		,,	,,	40267
2482·2	2n		,,	,,	40275
2480·2	2		,,	,,	40307
2479·9	2		,,	,,	40312
2478·6	2		,,	,,	40333
2476·9	2		,,	,,	40361
2473·1	6		,,	11·9	40423
2472·1	2		,,	,,	40439
2470·6	2		,,	,,	40464
2466·8	2n		0·72	,,	40526
2465·3	2		,,	,,	40551
2461·9	2		,,	,,	40607
2461·3	2		,,	12·0	40617
2455·5	2		,,	,,	40713
2454·0	2		,,	,,	40738
2452·4	2n		,,	,,	40764
2451·1	2n		,,	,,	40786
2449·1	2		,,	,,	40819
2448·3	2		,,	,,	40833
2445·6	2		,,	,,	40878
2444·6	2		,,	,,	40894
2441·8	2		,,	12·1	40941
2441·7	2		,,	,,	40943
2439·3	2		,,	,,	40983
2439·1	2		,,	,,	40987
2437·92	7		,,	,,	41006·5
2436·7	2		,,	,,	41027
2433·6	4		,,	,,	41079
2432·9	2		,,	,,	41091
2432·6	2		,,	,,	41096
2432·3	2		,,	,,	41101

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2431·6	2		0·72	12·1	41113
2429·2	2		,,	,,	41154
2428·4	2		,,	,,	41167
2425·0	2		,,	12·2	41225
2424·1	2		,,	,,	41240
2423·7	2		,,	,,	41247
2423·4	2		,,	,,	41252
2422·8	2n		,,	,,	41263
2421·3	2		0·71	,,	41288
2420·8	2		,,	,,	41297
2419·4	2		,,	,,	41321
2417·7	2		,,	,,	41350
2416·18	7		,,	,,	41375·5
2414·1	2		,,	,,	41411
2413·3	2		,,	,,	41425
2413·1	4		,,	,,	41428
2412·3	2		,,	12·3	41442
2411·6	2		,,	,,	41454
2410·6	2		,,	,,	41471
2409·7	2		,,	,,	41487
2408·8	2		,,	,,	41502
2408·5	2		,,	,,	41508
2407·7	2		,,	,,	41521
2407·3	2		,,	,,	41528
2406·9	2		,,	,,	41535
2406·4	2		,,	,,	41544
2405·2	5		,,	,,	41565
2404·2	2		,,	,,	41582
2403·6	2		,,	,,	41592
2401·9	2		,,	,,	41622
2398·2	2		,,	,,	41686
2395·8	2		,,	12·4	41728
2394·7	4		,,	,,	41747
2394·49	7		,,	,,	41750·1
2392·6	4		,,	,,	41784
2392·1	2		,,	,,	41792
2389·5	2		,,	,,	41838
2389·3	2		,,	,,	41841
2387·7	4		,,	,,	41869
2386·7	2		,,	,,	41887
2386·6	2		,,	,,	41889
2386·4	2		,,	,,	41892
2385·6	2		,,	,,	41906
2385·0	2		,,	,,	41917
2384·9	2		,,	,,	41918
2383·5	4		,,	,,	41943
2382·0	4		,,	12·5	41970
2379·6	2		,,	,,	42012
2378·7	4		,,	,,	42028
2376·0	2		,,	,,	42076
2375·4	6		,,	,,	42086
2372·2	2		0·70	,,	42143
2369·3	2		,,	,,	42195
2368·7	2		,,	12·6	42204
2367·5	4		,,	,,	42226

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2366·7	4		0·70	12·6	42240
2366·0	2		,,	,,	42252
2365·8	2		,,	,,	42256
2363·9	4		,,	,,	42290
2362·2	2		,,	,,	42320
2360·5	2		,,	,,	42351
2360·2	2		,,	,,	42356
2360·0	2		,,	,,	42360
2359·0	2		,,	,,	42378
2358·8	2		,,	,,	42381
2356·9	2		,,	,,	42414
2356·5	4		,,	,,	42423
2355·0	2		,,	,,	42450
2350·8	2		,,	12·7	42526
2350·0	2		,,	,,	42540
2348·2	2		,,	,,	42573
*2347·5	2		,,	,,	42586
2346·7	2		,,	,,	42600
2345·4	4		,,	,,	42624
2345·3	4		,,	,,	42625
2344·4	2		,,	,,	42642
2344·1	2		,,	,,	42647
2343·6	4		,,	,,	42656
2343·2	2		,,	,,	42664
2343·0	2		,,	,,	42667
2341·2	4		,,	,,	42700
2340·3	2		,,	12·8	42717
2339·7	2		,,	,,	42728
2337·6	2		,,	,,	42766
2337·2	2		,,	,,	42773
2336·7	4		,,	,,	42782
2334·6	5		,,	,,	42821
2331·7	2		,,	,,	42874
2330·0	2		,,	,,	42905
2329·8	2		,,	,,	42909
2329·3	2		,,	,,	42918
2327·4	2		,,	12·9	42953
2326·5	4		,,	,,	42970
2325·9	2		0·69	,,	42981
2323·3	2		,,	,,	43029
2323·0	2		,,	,,	43035
2322·8	2		,,	,,	43038
2320·2	4		,,	,,	43087
2319·8	4		,,	,,	43094
2318·6	4		,,	,,	43116
2317·3	2		,,	,,	43141
2316·2	4		,,	,,	43161
2314·1	2		,,	13·0	43200
2313·8	2		,,	,,	43206
2313·0	4		,,	,,	43221
2312·4	4		,,	,,	43232
2311·7	2		,,	,,	43245
2311·0	2		,,	,,	43258

* Double.

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2308·6	4		0·69	13·0	43303
2307·8	4		,,	,,	43318
2305·3	4		,,	,,	43365
2304·7	2		,,	,,	43387
2303·8	4		,,	,,	43394
2303·0	4		,,	,,	43409
2301·5	2		,,	,,	43437
2300·3	4		,,	13·1	43460
2299·8	4		,,	,,	43469
2298·3	4		,,	,,	43497
2297·6	4		,,	,,	43511
2297·2	4		,,	,,	43518
2296·6	4		,,	,,	43530
2292·1	2		,,	,,	43615
2290·0	2		,,	,,	43655
2289·4	2		,,	,,	43667
2288·7	2		,,	,,	43680
2288·4	2		,,	13·2	43686
2287·7	4		,,	,,	43699
2287·1	4		,,	,,	43710
2281·2	2		,,	,,	43824
2278·8	4		,,	,,	43870
2278·4	4		,,	,,	43877
2277·3	4		0·68	,,	43899
2276·6	4		,,	,,	43912
2276·2	2		,,	,,	43920
2275·7	4		,,	13·3	43930
2274·8	4		,,	,,	43947
2272·0	2		,,	,,	44001
2271·7	2		,,	,,	44007
2270·2	4		,,	,,	44036
2265·5	2		,,	,,	44127
2264·6	4		,,	,,	44145
2263·1	2		,,	13·4	44174
2260·1	2		,,	,,	44233
2259·4	2n		,,	,,	44247
2258·0	2n		,,	,,	44274
2257·0	2		,,	,,	44294
2256·2	4		,,	,,	44309
2254·0	4		,,	,,	44353
2253·2	2		,,	,,	44368
2250·7	2		,,	13·5	44412
2249·6	2		,,	,,	44439
2247·3	2		,,	,,	44485
2247·1	2		,,	,,	44489
2245·2	2n		,,	,,	44526
2242·7	2		,,	,,	44576
2241·7	2		,,	,,	44596
2228·1	2		0·67	13·6	44867
2226·5	4		,,	13·7	44900
2225·0	4		,,	,,	44930
2224·5	2		,,	,,	44940
2223·1	2		,,	,,	44968
2221·3	2		,,	,,	45005
2220·5	4		,,	,,	45021

NICKEL—*continued.*

Exner and Haschek Wave-length (Rowland) Spark Spectrum	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2216·5	4		0·67	13·7	45102
2211·2	2		"	13·8	45210
2210·4	4		"	"	45227
2206·8	2n		"	"	45300
2205·7	2n		"	"	45323
2203·7	2		"	13·9	45364
2201·4	4		"	"	45412
2192·5	2		"	"	45596
2188·2	2		"	14·0	45686
2185·6	4		0·66	"	45740
2180·7	2		"	"	45743
2179·5	2		"	14·1	45868
2177·4	2n		"	"	45912
2169·3	4		"	14·2	46084
2161·5	2		0·65	"	46250
2131·2	2		"	14·5	46908
2107·8	2		"	14·7	47428

Tables of Certain Mathematical Functions.—Interim Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Lieut.-Colonel ALLAN CUNNINGHAM, R.E. (*Secretary*), Lord KELVIN, Professor B. PRICE, Dr. J. W. L. GLAISHER, Professor A. G. GREENHILL, Professor W. M. HICKS, Major P. A. MACMAHON, R.A., *and* Professor A. LODGE, *appointed for calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.*

THE 'New Canon Arithmeticus' is a table quite similar to Jacobi's 'Canon Arithmeticus,' except that it is calculated for the base 2 throughout, whilst Jacobi's tables are for various bases.

The new table contains the solution of the congruence $2^x \equiv R$ (mod. p) for all primes $(p) < 1000$, and also of $2^x \equiv R$ (mod. p^n) for all powers of primes, $p^n < 1000$.

The left-hand table gives the *least* Residues (R) to Argument x; this table has been computed throughout by two computers independently, and the two copies have been checked throughout by both computers; thus this table is complete.

The right-hand table, giving the values of x (the exponent) to Argument R is merely a *re-arrangement* of the former; one copy is complete, the other copy is about half done, and checked in part.

The whole of the grant of 25*l.* for the year 1896–97 has been spent. The Committee ask for reappointment without further grant, the Secretary (Lieut.-Colonel Allan Cunningham, R.E.) undertaking to complete the second copy, and the checking of both copies (without asking for further grant) if the reappointment of the Committee be sanctioned.

The Application of Photography to the Elucidation of Meteorological Phenomena.—Seventh Report of the Committee, consisting of Mr. G. J. Symons (*Chairman*), Professor R. Meldola, Mr. J. Hopkinson, Mr. H. N. Dickson *and* Mr. A. W. Clayden (*Secretary*). (*Drawn up by the Secretary.*)

The work of the Committee has been continued during the past year, especially with regard to the measurements of cloud altitudes by means of photography. A considerable number of the results given in the report for 1896 have been verified by repeating the reduction of the plates.

In order to afford an efficient check upon the accuracy of last year's results, the altitude and azimuth of the sun were calculated by a different method and the altitude of the cloud deduced from a fresh set of co-ordinates measured on the plate.

In no case did the new determination differ more than about 3 per cent. from the old one, and in the majority of cases the agreement was very much closer. Particular attention was given to the instances in which the clouds had been determined to be floating at unusually great altitudes, and there is no doubt that those determinations are substantially correct.

During the last nine months it has not been possible to keep up a continuous series of photographs. The excessive rainfall of the early part of the year transformed the level ground between the camera stands and around one of them into a series of muddy pools, so that work was impracticable. But with this exception exposures have been made whenever opportunity offered, and the stock of negatives has been largely increased.

None of these additions have yet been reduced. The time available for the observations is limited, and it has been thought better to accumulate negatives during the finer part of the year and reserve them to be reduced in the winter, when opportunities for making observations are rare.

The warping of the ebonite shutters of the cameras has again proved troublesome, and steps have been taken to get them replaced by similar pieces of aluminium, a change which will probably be effected before this report is presented. Some delay was also caused by the mischievous behaviour of some unknown persons, who, on June 22, amused themselves by breaking the connecting wires and endeavouring to upset one of the camera stands.

Leclanché cells of the ordinary pattern have been substituted for the faulty dry cells formerly used, and have given complete satisfaction.

There is a good stock of plates in hand, and the photographs will be continued during the summer.

No fresh departure having been made, and the current expenses not being heavy, the grant made at Liverpool has not been drawn.

The work of the Committee being now limited to the investigation in the hands of the Secretary, who will continue it at his own expense, no grant in aid is asked, but the Committee would wish to be reappointed for another year.

Seismological Investigations.—Second Report of the Committee, consisting of Mr. G. J. SYMONS (*Chairman*), Dr. C. DAVISON *and* Mr. JOHN MILNE (*Secretaries*), Lord KELVIN, Professor W. G. ADAMS, Dr. J. T. BOTTOMLEY, Sir F. J. BRAMWELL, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Mr. G. F. DEACON, Professor J. A. EWING, Professor C. G. KNOTT, Professor G. A. LEBOUR, Professor R. MELDOLA, Professor J. PERRY, Professor J. H. POYNTING, *and* Dr. ISAAC ROBERTS.

CONTENTS.

I. *Report of Work done for the establishment of a Seismic Survey of the World.*

PROFESSOR MILNE has reported to the Committee that on January 31, 1895, he had issued a circular calling attention to the desirability of observing earthquake waves which had travelled great distances, with working drawings of the necessary installations.

Some months later Dr. E. von Rebeur-Paschwitz drew up suggestions for the establishment of an international system of earthquake stations. To this scheme Professor Milne and other members of the Committee lent their names.

After the death of von Rebeur these suggestions were translated into French and issued by Dr. G. Gerland of Strassburg, on his own responsibility.

For this reason, but more especially because individual efforts have not led to any definite results, the Committee have issued a letter to a number of observatories requesting co-operation in the observation of earthquakes which are propagated round and possibly through the earth.

Dr. Michie Smith has informed Professor Milne of the co-operation which might be expected from the Government of Madras. The Kew Committee have decided to establish an instrument.

Mr. Oldham, Director of the Geological Survey of India, has evinced a desire to assist in making observations. It is likely that Professor Turner of Oxford will purchase a seismograph, whilst others have made inquiries respecting the necessary installation. Sir Clement Markham has already offered his hearty support in carrying out a seismic survey of the world,

and there were strong reasons for believing that we might expect assistance from both the Royal Geographical and Royal Astronomical Societies.

Letter sent to various Observatories and Persons.

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Burlington House,
London, W.
....1897.

To...

....

SIR,—It has been established that the movements resulting from a large earthquake originating in any one portion of our globe can, with the aid of suitable instruments, be recorded at any other portion of the same; therefore the Seismological Investigation Committee of the British Association are desirous of your co-operation in an endeavour to extend and systematise the observation of such disturbances.

Similar instruments should be used at all stations; and the one recommended by this Committee as being simple to work, and one that furnishes results sufficiently accurate for the main objects in view, is indicated in the accompanying report (see pp. 2–4) by the letter M; a sketch of the same is shown on p. 7, whilst there is an example of one of its records on p. 49.

We desire to know whether you are disposed to purchase, and make observations with, one of these instruments, the cost of which, including photographic material to last one year, packed for shipment, is about 50*l.* Should you reply in the affirmative, we shall be pleased to arrange with a competent maker for the construction of an instrument for you, and to furnish instructions respecting installation and working. In case an instrument be established at your observatory, we should ask that notes of disturbances having an earthquake character be sent to us for analysis and comparison with the records from other stations. From time to time the results of these examinations would be forwarded to your observatory.

The first object we have in view is to determine the velocity with which motion is propagated round or possibly *through* our earth. To attain this, all that we require from a given station are the times at which various phases of motion are recorded; for which purpose, for the present at least, we consider an instrument recording a single component of horizontal motion to be sufficient. Other results which may be obtained from the proposed observations are numerous.

The foci of submarine disturbances, such, for example, as those which from time to time have interfered with telegraph-cables, may possibly be determined, and new light thrown upon changes taking place in ocean beds.

The records throw light upon certain classes of disturbances now and then noted in magnetometers and other instruments susceptible to slight movements; whilst local changes of level, some of which may have a diurnal character, may, under certain conditions, become apparent.

Trusting that you will find it possible to co-operate in this endeavour to extend our knowledge of the earth on which we live,

We remain, Sir (on behalf of the Committee),

Your obedient servants,

G. J. SYMONS, *Chairman.*

C. DAVISON, } *Joint Honorary*
J. MILNE, } *Secretaries.*

It is requested that Replies be addressed to—

THE SEISMOLOGICAL COMMITTEE, BRITISH ASSOCIATION,
BURLINGTON HOUSE, LONDON, W.

Letter sent to the Foreign Office on February 25, 1897.

Shide Hill House, Newport, I.W.,
February 25, 1897.

To the Under-Secretary of State for Foreign Affairs, Whitehall, London.

SIR,—I am directed by the Seismological Committee of the British Association for the Advancement of Science to state that they are anxious to obtain the assistance of the Marquess of Salisbury with a view to ascertaining, through Her Majesty's representatives in the countries mentioned, whether the Governments of the same would be disposed to co-operate in carrying out the observations indicated in the inclosed circular, which are considered of great scientific importance.

The countries with which the Committee desire to communicate are Chili, Peru, Ecuador, Venezuela, U.S. of Columbia, Mexico, Brazil, the Netherlands for Java, Greece, Spain, Portugal for the Azores, Russia for Russia and Siberia, and Japan.

Should his Lordship be pleased to grant the assistance of Her Majesty's Government in this matter, I shall have the honour to forward further copies of the circulars and pamphlets of which specimens are inclosed.

The Committee have learned that the Government of Madras are desirous to establish a station; whilst Admiral Wharton, Hydrographer to the Admiralty, considers the attainment of the objects in view of great practical value to his department.

I have the honour to remain, Sir,
Your most obedient and humble servant,
JOHN MILNE.

Communication with the Colonial Office.

A letter identical with that sent to the Foreign Office, and in which the following colonies were mentioned—Newfoundland, Bermuda, Barbados, Trinidad, Jamaica, Honduras, Guiana, St. Helena, the Falklands, Cyprus, and Malta—was forwarded on February 25, 1897, to the Colonial Office.

Communication with the Under-Secretary of State for India, April 10, 1897.

A letter in terms similar to the two preceding letters was addressed to the Under-Secretary of State for India asking for co-operation in establishing one station at Aden, three in India, and one in Further India.

The results of these three communications have been that the Marquess of Salisbury has granted the co-operation which was asked, a reply is promised from the Colonial Office, whilst the Under-Secretary of State for India has asked for and received more copies of our circulars and reports.

In addition to the above, thirty-one copies of circulars and reports have been distributed as follows:—

List of Observatories, &c., to which Circulars and Reports have been sent.

1. U.S.A. Cambridge, Mass. Harvard University. Professor E. C. Pickering.
2. „ St. Louis, Miss. Washington University. Professor W. S. Chaplin.
3. „ Terre Haute, Ind. Polytechnic Institute. Professor T. Gray.
4. „ Williams Bay, Wis. Yerkes Observatory. Professor G. E. Hale.
5. „ San Francisco, Berkeley, Cal. University of California. Professor Joseph Le Conte.
6. Australia, Perth. The Observatory. Ernest Cook, M.A
7. „ Adelaide. Sir C. Todd, K.C.M.G., F.R.S.
8. „ Melbourne. The Observatory. P. Baracchi.
9. „ Sydney. The Observatory. H. C. Russell, F.R.S.
10. New Zealand, Wellington. Sir J. Hector, F.R.S.
11. Africa, Cape Town. The Observatory. D. Gill, F.R.S.
12. „ Natal. The Observatory. E. Neville Nevill.
13. India, Madras. The Observatory. Dr. Michie Smith.
14. „ Calcutta. Geological Survey. R. D. Oldham.
15. Mauritius, Port Louis. Royal Alfred Observatory. T. F. Claxton.
16. Hawaii, Honolulu. Lieutenant A. G. Hawes.
17. Malta, Gozo. The College. Father James Scoles, S.J.
18. Manila. Meteorological Observatory. Father Saderra, S.J.
19. China, Shanghai, Zikawei. Rev. L. Froc, S.J.
20. „ Hong Kong. The Observatory. Dr. W. Doberk.
21. South America, Argentine. Cordova Observatory. W. G. Davies.
22. Canada, Toronto. The Observatory. Professor Stupart.
23. France, Paris, 126, Rue du Bac. M. A. d'Abbadie.
24. „ „ Bureau Central Météorologique. M. Professor Mascart.
25. Roumania, Bucharest. Institut Météorologique. Dr. Hepites.
26. Austria, Vienna. Hohewarte. Professor Dr. J. Hann.
27. Sweden, Upsala. Observatoire Météorologique. Professor H. H. Hildebrandsson.
28. Switzerland, Geneva. Professor F. A. Forel.
29. Spain, Cadiz. W. G. Forster.
30. Belgium, Uccle. Observatoire Royal de Belgique. A. Lancaster.
31. India, Calcutta. Geological Survey. C. L. Griesbach.

Offers for immediate co-operation have been received from Professors E. C. Pickering (No. 1), Dr. D. Gill (No. 11), and Professor Stupart (No. 22); Dr. Hepites (No. 25) will co-operate, using an instrument received from Dr. Tacchini; whilst Dr. J. Hann (No. 26) replies that he is establishing the Ehlert type of pendulum, and later may also use ours. Co-operation may be expected at some future time from Professor G. E. Hale (No. 4) and Mr. Ernest Cook (No. 6).

The applications Nos. 13, 14, and 21 will, it is hoped, receive a reply through the Under-Secretary of State for India.

The replies from Nos. 2, 9, 17, 19, and 30 indicate that co-operation cannot be expected.

From the remainder replies have not yet been received.

II. *Records of the Gray-Milne Seismograph.* *By* JOHN MILNE, *F.R.S., F.G.S.*

The first of the above seismographs constructed in 1883, partly at the expense of the British Association, still continues to be used as the standard instrument at the Central Observatory in Tokio.

I am indebted to the Director of that institution for the following records. The records with which they are continuous will be found in the 'Report of the British Association' for 1895, p. 115.

Catalogue of Earthquakes recorded at the Central Meteorological Observatory in Tokio between May 1895 *and February* 1896.

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			1895.							
			H. M. S.	M. S.						
1,523	IV.	6	0 30 27 P.M.	—	—	—	—	—	—	slight
1,524	„	9	6 20 34 P.M.	—	—	—	—	—	—	„
1,525	„	14	4 30 48 P.M.	—	—	—	—	—	—	„
1,526	„	16	11 46 41 A.M.	—	—	—	—	—	—	„
1,527	„	22	2 45 29 P.M.	—	—	—	—	—	—	slight, quick
1,528	„	25	6 38 43 A.M.	—	—	—	—	—	—	slight
1,529	„	25	7 08 02 A.M.	—	—	—	—	—	—	„
1,530	„	27	5 41 59 A.M.	—	—	—	—	—	—	„
1,531	„	28	8 33 36 A.M.	—	—	—	—	—	—	„
1,532	VI.	2	11 45 19 A.M.	—	—	—	—	—	—	„
1,533	„	2	8 38 0 P.M.	1 01	W.N.W., E.S.E.	1·3	0·8	slight		weak, slow
1,534	„	7	1 13 55 A.M.	—	—	—	—	—	—	slight
1,535	„	7	2 30 15 P.M.	—	—	—	—	—	—	„
1,536	„	11	0 46 23 A.M.	1 07	N.N.W., S.S.E.	0·6	0·4	—	—	weak, quick
1,537	„	15	4 30 31 P.M.	—	—	—	—	—	—	slight
1,538	„	16	1 17 38 A.M.	—	—	—	—	—	—	„
1,539	„	20	2 51 48 A.M.	—	—	—	—	—	—	„
1,540	„	20	11 56 55 A.M.	10 0	S.–N.	0·3	0·2	slight		weak, slow
1,541	„	24	1 47 57 P.M.	1 28	S.W., N.E.	0·6	0·4	nothing		weak, quick
1,542	„	29	7 03 27 P.M.	—	—	—	—	—	—	slight
1,543	„	30	7 16 0 A.M.	—	—	—	—	—	—	„
1,544	VII.	2	9 12 57 A.M.	—	—	—	—	—	—	„
1,545	„	4	8 54 11 A.M.	—	—	—	—	—	—	„
1,546	„	3	10 42 07 P.M.	—	—	—	—	—	—	„
1,547	„	9	2 26 59 P.M.	—	—	—	—	—	—	„
1,548	„	10	11 08 36 A.M.	—		—	—	—	—	„
1,549	„	11	3 52 07 A.M.	—		—	—	—	—	„
1,550	„	15	9 23 40 A.M.	—	—	—	—	—	—	„
1,551	„	17	10 0 8 P.M.	1 25	S.W., N.E.	0·5	0·7	0·3	0·1	rather weak, quick
1,552	„	18	9 55 42 P.M.	—	—	—	—	—	—	slight
1,553	„	27	0 09 03 A.M.	0 37	S.–N.	0·5	0·4	slight,	very	weak, slow
1,554	„	31	4 44 30 P.M.	0 39	E.S.E., W.N.W.	1·0	0·5	—	—	„
1,555	VIII.	1	3 53 50 A.M.	—	—	—	—	—	—	slight
1,556	„	1	7 32 35 P.M.	—	—	—	—	—	—	„
1,557	„	3	5 36 48 A.M.	—	—	—	—	—	—	„
1,558	„	24	11 16 8 P.M.	1 29	S.–N.	0·5	0·4	—	—	weak, slow
1,559	„	31	9 37 21 P.M.	—	—	—	—	—	—	slight
1,560	IX.	3	8 18 11 P.M.	—	—	—	—	—	—	„
1,561	„	6	0 37 26 A.M.	—	—	—	—	—	—	„
1,562	„	7	8 02 05 A.M.	—	—	—	—	—	—	„
1,563	„	9	9 53 22 P.M.	0 37	S.–N.	0·8	0·4	—	—	weak, slow
1,564	„	10	0 43 52 P.M.	—	—	—	—	—	—	slight
1,565	„	18	3 18 54 P.M.	—	—	—	—	—	—	„
1,566	„	21	11 24 30 A.M.	—	—	—	—	—	—	„
1,567	„	21	11 03 27 P.M.	—	—	—	—	—	—	„
1,568	„	24	1 48 10 A.M.	1 08	N.N.E., S.S.W.	0·6	1·7	slight,	very	weak, quick
1,569	„	25	2 52 12 A.M.	—	—	—	—	—	—	slight
1,570	X.	4	6 01 12 P.M.	—	—	—	—	—	—	„
1,571	„	8	1 16 01 P.M.	—	—	—	—	—	—	(thing fallen down to south)
1,572	„	11	3 11 53 P.M.	0 55	S.–N.	0·2	6·1	0·2	1·3	strong, quick
1,573	„	12	2 18 23 P.M.	—	—	—	—	—	—	slight
1,574	„	13	8 34 50 A.M.	—	—	—	—	—	—	„
1,575	„	13	1 33 57 P.M.	—	—	—	—	—	—	„
1,576	„	15	6 35 35 A.M.	—	—	—	—	—	—	„
1,577	„	15	3 05 11 P.M.	—	—	—	—	—	—	„
1,578	„	17	1 49 26 P.M.	—	—	—	—	—	—	„
1,579	„	23	6 56 26 P.M.	0 23	S.–N.	0·4	0·5	slight,	very	weak, quick
1,580	„	24	6 55 53 A.M.	—	—	—	—	—	—	slight
1,581	„	24	7 48 17 P.M.	—	—	—	—	—	—	„
1,582	„	25	11 30 12 A.M.	—	—	—	—	—	—	„
1,583	„	25	8 24 03 P.M.	—	—	—	—	—	—	„
1,584	„	27	11 44 23 A.M.	—	—	—	—	—	—	„
1.585	„	27	4 33 49 P.M.	—	—	—	—	—	—	„

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,586	X.	28	0 17 51 A.M.	—	—	—	—	—	—	slight
1,587	XI.	7	0 13 28 A.M.	—	—	—	—	—	—	„
1,588	„	8	3 43 34 A.M.	—	—	—	—	—	—	„
1,589	„	11	3 9 39 A.M.	—	—	—	—	—	—	„
1,590	„	19	3 27 23 P.M.	—	—	—	—	—	—	„
1,591	„	22	10 47 54 A.M.	—	—	—	—	—	—	„
1,592	„	28	6 12 55 A.M.	0 43	S.E., N.W.	0·3	0·5	—	—	weak, quick
1,593	XII.	10	11 19 33 A.M.	—	—	—	—	—	—	slight
1,594	„	12	11 15 32 A.M.	—	—	—	—	—	—	„
1,595	„	31	6 04 27 A.M.	—	—	—	—	—	—	„
					1896.					
1,596	I.	1	9 11 23 P.M.	10 0	S.–N.	0·3	0·2	noth	ing	weak, slow
1,597	„	2	6 13 19 P.M.	—	—	—	—	—	—	slight
1,598	„	3	10 12 21 P.M.	—	—	—	—	—	—	„
1,599	„	5	11 24 27 P.M.	—	—	—	—	—	—	„
1,600	„	7	4 10 56 P.M.	—	—	—	—	—	—	„
1,601	„	7	7 0 44 P.M.	—	—	—	—	—	—	„
1,602	„	9	10 17 16 P.M.	9 23	S.–N.	2·2	16·2	0·5	0·6	strong, slow
1,603	„	9	10 42 20 P.M.	—	—	—	—	—	—	slight
1,604	„	9	10 50 37 P.M.	—	—	—	—	—	—	„
1,605	„	9	11 14 49 P.M.	—	—	—	—	—	—	„
1,606	„	10	0 31 42 A.M.	2 15	S.–N.	0·9	0·5	—	—	weak, slow
1,607	„	10	0 39 09 A.M.	—	—	—	—	—	—	slight
1,608	„	10	0 46 17 A.M.	—	—	—	—	—	—	„
1,609	„	10	0 46 32 A.M.	—	—	—	—	—	—	„
1,610	„	10	1 22 01 A.M.	—	—	—	—	—	—	„
1,611	„	10	2 12 51 A.M.	—	—	—	—	—	—	„
1,612	„	10	2 50 24 A.M.	—	—	—	—	—	—	„
1,613	„	10	5 52 20 A.M.	2 43	N.W., S.E.	1·4	1·2	—	—	weak, slow
1,614	„	10	6 41 41 A.M.	—	—	—	—	—	—	slight
1,615	„	10	7 04 21 A.M.	—	—	—	—	—	—	„
1,616	„	10	11 24 29 A.M.	4 22	S.–N.	1·3	1·7	—	—	weak, slow
1,617	„	10	4 42 46 P.M.	4 0	W.N.W., E.S.E.	1·2	1·0	—	—	„
1,618	„	10	8 08 44 P.M.	—	—	—	—	—	—	slight
1,619	„	10	10 21 59 P.M.	—	—	—	—	—	—	„
1,620	„	11	0 33 05 A.M.	—	—	—	—	—	—	„
1,621	„	11	5 50 08 A.M.	—	—	—	—	—	—	„
1,622	„	11	7 06 43 A.M.	—	—	—	—	—	—	„
1,623	„	11	8 49 12 A.M.	—	—	—	—	—	—	„
1,624	„	11	10 36 65 A.M.	—	—	—	—	—	—	„
1,625	„	11	4 47 30 P.M.	—	—	—	—	—	—	„
1,626	„	12	11 06 37 P.M.	36 0	E.–W.	0·2	0·4	0·2	0·2	weak, quick
1,627	„	13	5 26 35 A.M.	—	—	—	—	—	—	slight
1,628	„	15	4 24 54 A.M.	—	—	—	—	—	—	„
1,629	„	16	2 42 31 A.M.	—	—	—	—	—	—	„
1,630	„	16	4 14 25 A.M.	—	—	—	—	—	—	„
1,631	„	19	6 08 22 P.M.	2 10	S.–N.	1·0	0·3	—	—	weak, slow
1,632	„	22	3 11 25 A.M.	—	—	—	—	—	—	slight
1,633	„	22	4 43 40 A.M.	2 50	S.S.E., N.N.W.	0·5	2·3	slight,	very	weak, quick
1,634	„	22	5 28 15 A.M.	30 0	S.S.W., N.N.E.	0·2	0·3	—	—	„
1,635	„	22	7 16 27 A.M.	—	—	—	—	—	—	slight
1,636	„	22	6 16 29 P.M.	—	—	—	—	—	—	„
1,637	„	22	3 30 09 A.M.	—	—	—	—	—	—	„
1,638	II.	2	5 02 06 A.M.	—	—	—	—	—	—	„
1,639	„	5	5 10 17 P.M.	—	—	—	—	—	—	„
1,640	„	9	7 47 21 P.M.	—	—	—	—	—	—	„
1,641	„	12	6 37 44 A.M.	1 09	S.S.E., N.N.W.	0·5	0·3	—	—	weak, quick
1,642	„	14	1 56 11 A.M.	0 40	S.–N.	1·0	0·3	0.3	—	„
1,643	„	14	2 03 44 A.M.	—	—	—	—	—	—	rather weak
1,644	„	15	1 16 20 A.M.	—	—	—	—	—	—	slight
1,645	„	18	about 5 13 0 P.M.	—	—	—	—	—	—	„
1,646	„	18	10 19 27 P.M.	—	—	—	—	—	—	„
1,647	„	23	7 41 47 P.M.	3 55	N., W.S.E.	1·0	3·7	slight,	very	weak, slow
1,648	„	23	9 35 50 P.M.	—	—	—	—	—	—	slight
1,649	„	24	9 56 03 P.M.	—	—	—	—	—	—	„
1,650	„	25	0 59 59 A.M.	—	—	—	—	—	—	„

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion.		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,651	II.	25	7 58 25 A.M.	—	—	—	—	—	—	slight
1,652	„	28	9 35 15 A.M.	—	—	—	—	—	—	„
1,653	„	29	5 56 35 A.M.	3 7	E.–W.	0·3	0·2	—	—	weak, quick
1,654	„	29	11 27 02 P.M.	—	—	—	—	—	—	slight
1,655	III.	1	5 29 25 P.M.	—	—	—	—	—	—	„
1,656	„	6	7 40 46 P.M.	—	—	—	—	—	—	„
1,657	„	6	11 51 31 P.M.	2 0	S.W., N.E.	0·6	4·3	0·6	0·4	weak, quick
1,658	„	9	10 16 15 A.M.	—	—	—	—	—	—	slight
1,659	„	10	8 54 48 P.M.	—	—	—	—	—	—	„
1,660	„	12	7 12 16 A.M.	—	—	—	—	—	—	„
1,661	„	13	2 36 23 A.M.	—	—	—	—	—	—	„
1,662	„	14	4 44 32 A.M.	—	—	—	—	—	—	„
1,663	„	14	10 15 32 P.M.	—	—	—	—	—	—	„
1,664	„	14	11 41 48 P.M.	—	—	—	—	—	—	„
1,665	„	16	10 33 16 P.M.	—	—	—	—	—	—	„
1,666	„	17	2 37 08 A.M.	—	—	—	—	—	—	„
1,667	„	20	3 35 57 A.M.	—	—	—	—	—	—	„
1,668	„	20	11 32 20 A.M.	—	—	—	—	—	—	„
1,669	„	26	6 28 49 P.M.	—	—	—	—	—	—	„
1,670	IV.	1	2 53 13 A.M.	—	—	—	—	—	—	„
1,671	„	1	2 50 27 P.M.	—	—	—	—	—	—	„
1,672	„	2	1 41 55 A.M.	1 18	E.–W.	1·2	0·2	—	—	weak, slow
1,673	„	2	11 38 57 A.M.	—	—	—	—	—	—	slight
1,674	„	10	5 39 53 P.M.	0 45	S.–N.	0·5	0·2	—	—	weak, slow
1,675	„	11	10 35 35 A.M.	—	—	—	—	—	—	slight
1,676	„	11	10 58 49 P.M.	2 52	N.W., S.E.	0·3	1·5	0·3	0·2	weak, quick
1,677	„	13	10 05 07 P.M.	—	—	—	—	—	—	slight
1,678	„	13	10 13 47 P.M.	—	—	—	—	—	—	„
1,679	„	15	7 41 39 A.M.	—	—	—	—	—	—	„
1,680	„	15	8 26 27 P.M.	—	—	—	—	—	—	„
1,681	„	19	7 59 02 P.M.	4 07	N.N.W., S.S.E.	1·2	0·9	—	—	weak, slow
1,682	„	20	1 36 17 A.M.	1 50	W.N.W., E.S.E.	1·5	0·6	—	—	„
1,683	„	20	0 23 13 P.M.	—	—	—	—	—	—	slight
1,684	„	21	9 05 03 A.M.	1 57	S.W., N.E.	1·6	0·6	—	—	weak, slow
1,685	„	21	0 19 40 P.M.	—	—	—	—	—	—	slight
1,686	„	23	0 37 41 A.M.	—	—	—	—	—	—	„
1,687	„	23	5 08 45 A.M.	1 21	N.N.W., S.S.E.	0·3	0·5	—	—	weak, quick
1,688	„	26	7 02 37 A.M.	—	—	—	—	—	—	slight
1,689	„	26	10 49 56 A.M.	2 06	S.S.E., N.N.W.	0·7	2·5	0·6	0·2	weak, quick
1,690	„	25?	5 28 11 A.M.	—	—	—	—	—	—	slight
1,691	V.	4	7 37 62 A.M.	—	—	—	—	—	—	„
1,692	„	5	3 01 50 A.M.	—	—	—	—	—	—	„
1,693	„	7	2 37 17 P.M.	1 55	W.N.W., E.S.E.	1·3	0·8	—	—	weak, slow
1,694	„	11	11 32 58 P.M.	—	—	—	—	—	—	slight
1,695	„	16	0 26 13 A.M.	1 25	S.E., N.W.	0·4	0·4	0·3	0·1	weak, quick
1,696	„	17	3 39 59 P.M.	2 20	E.S.E., W.N.W.	1·2	1·8	0·7	0·2	weak, slow
1,697	„	21	3 58 33 A.M.	—	—	—	—	—	—	slight
1,698	„	26	6 43 31 P.M.	—	—	—	—	—	—	„
1,699	„	26	8 20 54 P.M.	0 30	S.W., N.E.	0·3	0·3	—	—	weak, quick
1,700	„	29	1 18 50 A.M.	—	—	—	—	—	—	slight
1,701	VI.	1	7 25 52 P.M.	—	—	—	—	—	—	„
1,702	„	4	3 32 52 A.M.	—	—	—	—	—	—	„
1,703	„	6	6 26 41 P.M.	—	—	—	—	—	—	„
1,704	„	7	11 18 15 A.M.	—	—	—	—	—	—	„
1,705	„	7	9 50 09 P.M.	—	—	—	—	—	—	„
1,706	„	8	5 23 30 P.M.	—	—	—	—	—	—	„
1,707	„	11	6 02 17 A.M.	—	—	—	—	—	—	„
1,708	„	11	6 51 59 P.M.	—	—	—	—	—	—	„
1,709	„	14	11 03 08 P.M.	—	—	—	—	—	—	„
1,710	„	15	5 44 43 P.M.	—	—	—	—	—	—	„
1,711	„	15	7 34 14 P.M.	3 48	W.N.W., E.S.E.	1·3	0·8	slight,	very	weak, slow
1,712	„	15	about 7 44 0 P.M.	—	—	—	—	—	—	slight
1,713	„	15	8 33 53 P.M.	—	—	—	—	—	—	„
1,714	„	15	9 0 38 P.M.	—	—	—	—	—	—	„
1,715	„	15	9 02 31 P.M.	—	—	—	—	—	—	„
1,716	„	15	9 14 14 P.M.	—	—	—	—	—	—	„
1,717	„	15	9 27 35 P.M.	—	—	—	—	—	—	„
1,718	„	15	9 56 39 P.M.	—	—	—	—	—	—	„

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,719	VI.	16	0 49 48 A.M.	—	—	—	—	—	—	slight
1,720	,,	16	1 05 22 A.M.	—	—	—	—	—	—	,,
1,721	,,	16	1 32 14 A.M.	—	—	—	—	—	—	,,
1,722	,,	16	4 16 30 A.M.	4 55	W.N.W.. E.S.E.	0·8	0·4	slight,	very	weak, quick
1,723	,,	16	5 01 09 A.M.	—	—	—	—	—	—	slight
1,724	,,	16	6 40 01 A.M.	—	—	—	—	—	—	,,
1,725	,,	16	8 01 14 A.M.	3 20	W.S.W., E.N.E.	1·0	0·3	slight,	very	weak, quick
1,726	,,	16	8 15 20 A.M.	—	—	—	—	—	—	slight
1,727	,,	16	8 16 29 A.M.	—	—	—	—	—	—	,,
1,728	,,	16	9 32 01 A.M.	—	—	—	—	—	—	,,
1,729	,,	16	9 47 11 A.M.	—	—	—	—	—	—	,,
1,730	,,	16	0 0 0 P.M.	—	—	—	—	—	—	,,
1,731	,,	16	1 26 12 P.M.	—	—	—	—	—	—	,,
1,732	,,	16	1 28 38 P.M.	—	—	—	—	—	—	,,
1,733	,,	16	1 29 48 P.M.	—	—	—	—	—	—	,,
1,734	,,	16	3 11 31 P.M.	—	—	—	—	—	—	,,
1,735	,,	16	4 23 27 P.M.	—	—	—	—	—	—	,,
1,736	,,	16	4 44 58 P.M.	—	—	—	—	—	—	,,
1,737	,,	16	5 46 18 P.M.	—	—	—	—	—	—	,,
1,738	,,	16	6 31 18 P.M.	—	—	—	—	—	—	,,
1,739	,,	16	9 58 03 P.M.	—	—	—	—	—	—	,,
1,740	,,	16	10 33 29 P.M.	1 05	N.N.E., S.S.W.	0·7	0·2	—	—	weak, quick
1,741	,,	17	7 47 27 A.M.	—	—	—	—	—	—	slight
1,742	,,	17	8 41 19 A.M.	—	—	—	—	—	—	,,
1,743	,,	17	10 30 20 A.M.	—	—	—	—	—	—	,,
1,744	,,	17	0 48 28 P.M.	3 25	E.N.E., W.S.W.	1·4	0·4	slight,	very	weak, slow
1,745	,,	17	3 13 39 P.M.	—	—	—	—	—	—	slight
1,746	,,	18	5 49 38 P.M.	—	—	—	—	—	—	,,
1,747	,,	22	2 53 59 P.M.	—	—	—	—	—	—	,,
1,748	,,	24	11 24 17 P.M.	—	—	—	—	—	—	,,
1,749	,,	25	2 09 19 P.M.	—	—	—	—	—	—	,,
1,750	,,	26	7 27 06 P.M.	—	—	—	—	—	—	,,
1,751	,,	30	7 26 03 A.M.	—	—	—	—	—	—	,,
1,752	VII.	1	5 30 43 A.M.	—	—	—	—	—	—	,,
1,753	,,	1	7 13 50 P.M.	—	—	—	—	—	—	,,
1,754	,,	3	11 38 17 P.M.	—	—	—	—	—	—	,,
1,755	,,	5	4 59 28 P.M.	—	—	—	—	—	—	,,
1,756	,,	6	0 25 57 A.M.	—	—	—	—	—	—	,,
1,757	,,	6	2 21 25 A.M.	—	—	—	—	—	—	,,
1,758	,,	7	6 35 26 P.M.	—	—	—	—	—	—	,,
1,759	,,	7	9 39 33 A.M.	—	—	—	—	—	—	,,
1,760	,,	9	10 03 40 A.M.	—	—	—	—	—	—	,,
1,761	,,	10	4 49 20 P.M.	—	—	—	—	—	—	,,
1,762	,,	11	7 44 27 A.M.	—	—	—	—	—	—	,,
1,763	,,	12	9 35 26 P.M.	—	—	—	—	—	—	,,
1,764	,,	13	7 53 35 P.M.	—	—	—	—	—	—	,,
1,765	,,	15	10 31 12 P.M.	—	—	—	—	—	—	,,
1,766	,,	16	9 43 20 P.M.	—	—	—	—	—	—	,,
1,767	,,	17	10 41 47 P.M.	—	—	—	—	—	—	,,
1,768	,,	18	0 59 44 P.M.	1 58	S.S.E., N.N.W.	0·6	0·7	slight,	very	slight, quick
1,769	,,	18	3 36 17 P.M.	—	—	—	—	—	—	slight
1,770	,,	19	4 12 32 P.M.	—	—	—	—	—	—	,,
1,771	,,	19	7 44 15 P.M.	—	—	—	—	—	—	,,
1,772	,,	29	0 56 33 P.M.	—	—	—	—	—	—	,,
1,773	,,	29	5 63 36 P.M.	2 16	S.W., N.E.	0·8	3·2	slight,	very	weak, slow, stop clock
1,774	VIII.	1	11 49 04 A.M.	2 09	S.E., N.W.	0·8	2·2	0·4	0·3	weak, quick
1,775	,,	11	8 23 36 A.M.	20 0	S.W., N.E.	0·3	0·6	slight,	very	rather weak, quick
1,776	,,	12	4 31 56 P.M.	—	—	—	—	—	—	slight
1,777	,,	13	10 50 37 A.M.	—	—	—	—	—	—	,,
1,778	,,	14	7 33 28 A.M.	—	—	—	—	—	—	,,
1,779	,,	14	8 51 21 A.M.	—	—	—	—	—	—	,,
1,780	,,	17	4 28 48 A.M.	—	—	—	—	—	—	,,
1,781	,,	20	6 05 37 P.M.	0 50	E.N.E., W.S.W.	0·3	2·9	0·2	0·25	weak, quick
1,782	,,	21	1 24 41 A.M.	—	—	—	—	—	—	slight
1,783	,,	23	1 37 10 P.M.	—	—	—	—	—	—	,,
1,784	,,	26	5 49 37 P.M.	—	—	—	—	—	—	,,
1,785	,,	27	7 25 0 P.M.	—	—	—	—	—	—	,,

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M.S.						
1,786	VIII.	29	7 01 01 P.M.	—	—	—	—	—	—	slight
1,787	„	30	7 32 11 A.M.	—	—	—	—	—	—	„
1,788	„	31	8 38 21 A.M.	—	—	—	—	—	—	„
1,789	„	31	4 42 11 P.M.	—	—	slig hori	ht, zontal	—	—	slight, slow
1,790	„	31	5 09 33 P.M.	—	Destructive in Akita		„	slight,	very	„
1,791	IX.	1	2 56 51 P.M.	—	—	—	—	—	—	slight
1,792	„	4	3 15 27 P.M.	—	—	—	—	—	—	„
1,793	„	5	11 07 46 P.M.	—	—	slig hori	ht, zontal	—	—	„
1,794	„	10	11 17 53 A.M.	—	—		„	slight,	very	slight, quick
1,795	„	12	8 12 54 P.M.	—	—	—	—	—	—	slight
1,796	„	12	11 16 25 P.M.	—	—	—	—	—	—	„
1,797	„	19	8 59 21 P.M.	—	—	—	—	—	—	„
1,798	X.	1	2 38 07 P.M.	—	—	—	—	—	—	„
1,799	„	7	9 22 35 A.M.	—	—	—	—	—	—	„
1,800	„	8	1 43 08 P.M.	—	—	—	—	—	—	„
1,801	„	10	10 56 01 A.M.	—	—	—	—	—	—	„
1,802	„	28	5 51 26 P.M.	—	—	—	—	—	—	„
1,803	XI.	6	7 42 59 P.M.	—	—	—	—	—	—	„
1,804	„	7	11 07 17 A.M.	—	—	—	—	—	—	„
1,805	„	10	8 06 21 A.M.	—	—	—	—	—	—	„
1,806	„	11	1 36 58 P.M.	—	—	—	—	—	—	„
1,807	„	13	0 13 61 P.M.	—	—	—	—	—	—	„
1,808	„	16	6 06 02 P.M.	—	—	—	—	—	—	„
1,809	„	18	11 08 19 A.M.	2 50	S.S.W., N.N.E.	1·0	0·4	—	—	slight, slow
1,810	XII.	7	10 37 29 A.M.	—	—	—	—	—	—	slight
1,811	„	9	7 56 41 A.M.	—	—	—	—	—	—	„
1,812	„	10	4 44 01 P.M.	—	—	—	—	—	—	„
1,813	„	12	11 22 26 A.M.	—	—	—	—	—	—	„
1,814	„	13	4 02 47 P.M.	—	—	—	—	—	—	„
*1,815	„	17	1 17 25 A.M.	0 67	S.S.E., N.N.W.	0·2	1·9	0·3	0·6	weak, very quick
						First begins very slight, and after 5 seconds it shows strong horizontal motion, and continued 9 seconds; then gradually became quieter.				

* Other shocks were:—Yokohama, 1h. 17m. 39s., slight; Yokosuka, 1h. 17m. 30s., weak; Maibashi, 1h. 30m. 03s., slight; Gifu, 1h. 20m. 46s., slight. This shock is supposed to represent a landslip in the Bay of Tokio, for it only extends round Tokio.

III. *On the Installation and working of Milne's Horizontal Pendulum.* *By* JOHN MILNE, *F.R.S., F.G.S.*

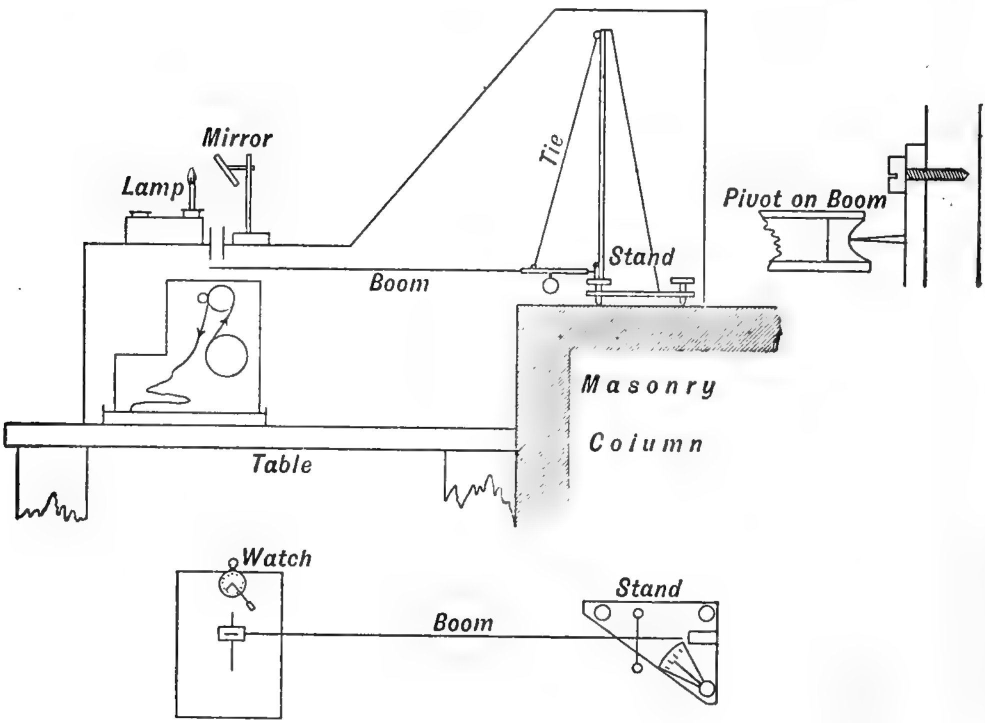
General Remarks.—As it has been established that the movements resulting from a large earthquake originating in any one portion of our globe can, with the aid of suitable instruments, be recorded in any other portion of the same, the Seismological Committee of the British Association have asked for the co-operation of observers in various parts of the world in an endeavour to extend and systematise the observation of such disturbances. The first object in view is to determine the velocity with which motion is propagated round and possibly through our earth. To attain this, all that is required at a given station is the times at which various phases of motion are recorded, for which purpose, for the present at least, an instrument recording a single component of horizontal motion is sufficient. Other results which may be obtained from the proposed observations are

numerous. The foci of submarine disturbances—such, for example, as those which from time to time have interfered with telegraph cables—may possibly be determined, and new light thrown upon changes taking place in ocean beds. The records throw light upon certain classes of disturbances now and then noted in magnetometers and other instruments susceptible to slight movements, whilst local changes in level, some of which may have a diurnal character, may, under certain conditions, become apparent.

The Instrument.—The general features of a type of instrument which the Committee have selected as being sufficient for the attainment of the objects in view are shown in the accompanying sketch.

The instrument consists of an iron bed-plate and stand carried on

Fig. 1.



three levelling screws. Resting against a needle-point or pivot projecting from the base of the stand, and held in a nearly horizontal position by a tie, is a light aluminium boom. Attached to the outer end of this boom there is a small rectangular plate in which there are two slits, one of which is large and the other is small. Partly for the purpose of balancing the weight of the outer end of the boom, and partly for obtaining the 'steady point' of a seismograph between the attachment of the tie to the pivot, a weighted cross-bar is pivoted.

When the boom swings to the right or left, the rectangular plate with its slits passes to the right and left across a fixed slit in the lid of a box, inside which a 2-inch (50 mm.) strip of bromide paper is being driven by clockwork. Light from a lamp is reflected downwards by a mirror to cover the whole of the latter slit. It however only enters the box to

the right and left of the floating-plate and through the slits in the same. When the boom is steady, the resulting photogram on the moving bromide paper will be, when developed, that of a white band equal in width to that of the moving-plate, down the centre of which band are two very clearly defined lines, one of which is thick and the other thin (figs. 2, 3, and 5). To the right and left of this white band the paper will have been blackened by the light which entered at the two ends of the fixed slit. On one edge of one of these black bands, at intervals of about 50 mm., there will be seen a series of white marks which have been produced by the minute-hand of a watch, the broadened extremity of which has hourly at the half-hour passed over the end of the fixed slit, and for a period of about one minute eclipsed the light.

Should the clock at any time have failed to drive the bromide strip with regularity this will at once be seen by differences in the distances between successive time marks.

Installation.—The instrument may be placed on any solid pier in an observatory, on a specially constructed pier in the ground-floor of an ordinary dwelling, or in a hut or shed in the open. The room should be dry, which will generally be the case if means are provided for ample ventilation. In order that the photographic paper may be examined or removed at any time, the windows of the room should be provided with shutters, through one of which red light can be admitted. A column or pier of convenient size may be two bricks, or 18 inches (45 cm.) square, which rises 2 feet 8 inches (80 cm.) above the floor. The base of this may rest on a 6-inch (15 cm.) layer of concrete, which in turn rests on a bed of gravel rammed in the natural earth. The top of such a column may be made smooth by a thin facing of cement, whilst its sides should be oriented N.-S. and E.-W. It is convenient to have space to pass round the pier on three sides. The table, which projects from the column in a N.-S. direction and carries the clock-box should be strong, 3 feet 8 inches (1·12 m.) long, 3 feet 7 inches (1·09 m.) broad, and rise 1 foot 8 inches (50 cm.) above the floor of the room. The upper surface of this table is therefore exactly 1 foot (30 cm.) below the top of the column. If an existing pier is used the height of the table must be increased or decreased to maintain the last dimension. The table is made wide to give space for the clock-box, which is run out upon it from its covering-case when removing a film.

The installation may be on an alluvium plain or on solid rock.

Adjustment of the Pendulum.—The instrument is to be so placed that the boom is in the meridian, or points N.-S. The balance weight is to be placed at a distance of $3\frac{1}{2}$ inches (87 mm.) from the pivot, and the attachment of the tie at a distance of about 5 inches (125 mm.). At the latter point, but not shown in the sketch, there is a small upright, from the top of which a thread is carried to within about 9 inches (22 cm.) from the outer end of the boom. This is to prevent the boom from sagging. After the bed-plate of the stand has been made approximately level, the boom is suspended, as shown in the sketch, with its outer end about $\frac{1}{8}$ inch (3 mm.) above the top of the clock-box. To increase or decrease this distance the tie, the last inch or so of which at its upper end is made of unspun silk, may be shortened or lengthened by means of a screw at the top of the stand.

The next point is to give the boom a certain sensibility, which increases as the period of its swing increases. The sensibility which must be arrived at is that which corresponds to an adjustment that

results in the pendulum having a period of 15 seconds—that is to say, it is reached when the pendulum makes one complete swing or one back and forward motion in 15 seconds. To make this adjustment the pivot against which the boom abuts may be moved in and out until the desired period is approximately obtained, after which the front screw of the stand may be raised or lowered until the adjustment is completed. To observe the period the observer presses with his hand against the side of the column. This sets the boom in motion. He then goes to the end of the instrument, and, looking downwards through a plate of glass beneath the lamp, watches the rectangular plate on the end of the boom and notes with a watch how many seconds it takes for the boom, as it slowly moves across the scale of millimetres fixed in the top of the clock-box parallel to the slit in the same, to complete a back and forward motion. For various reasons it seems that in all forms of horizontal pendulums this quantity will not remain constant for any great length of time. It therefore must be noted, say, once a week, and if any marked change has taken place the instrument should be readjusted. For stations founded on rock the pendulum may be adjusted to have a period of 18 seconds; but with a pendulum having this sensibility in a station on alluvium, the diurnal motion may exceed the width of the slit in the clock-box, and with changes of weather and the seasons the wandering of the pendulum to one side or the other will be so great that readjustments will be continually required.

The boom is to be brought into a central position by turning one or other of the two back screws in the bed-plate.

The Sensibility of the Instrument.—The distance between the two back screws of the instrument is 150 mm. The front one of these has 0·5 mm. pitch, so that one complete turn of this would tilt the stand through an angle the tangent of which would be measured by $\frac{1}{2}\times\frac{1}{150}=\frac{1}{300}$. By means of a lever fitting the head of the screw, rather than giving it a complete turn, it may be turned 1°, 2°, or any other fraction of a complete turn that may be desired, this quantity being indicated by a pointer attached to the screw which moves over an arc graduated in degrees. For example, assuming that the boom has a period of 18 seconds, and we find by several trials that a 1° turn of the test-screw corresponds to a deflection of the outer end of the boom of 5 mm., as shown on the scale opposite the slit in the clock-box, and assuming, further, that we can read displacements on the photogram of 1 mm., under these circumstances we can measure tiltings the angular values of which would be

$$\frac{1}{2}\times\frac{1}{150}\times\frac{1}{360}\times\frac{1}{5}=\frac{1}{540000};$$

and because 1 sec. of arc$=1/206265$, it follows that 1 mm. deflection of the outer end of the boom corresponds to a tilt of $0''\cdot38$.

If we read deflections to within half a millimetre, to do which there is no difficulty, the sensibility of the instrument is doubled. For the object in view this is not required, and if a deflection of 1 mm. is obtained for a tilt of $1''$ to $0''\cdot5$, this will be sufficient.

Clock-box.—This, which can be run on rails in and out of the instrument-case, has a cover which is removed to wind the clock and put new paper in the roll. Once a day, when the lamp is filled and trimmed, and the watch is wound, this cover is removed, and the 3 or 4 feet of paper

which has accumulated is roughly rolled up. At this time the date may be written in pencil on the bromide film on the top of the upper roll. The small top roll shown in the sketch should barely touch its neighbour, whilst a corresponding roll in contact with the driving-roll should press somewhat tightly on the latter. These two latter rolls are not shown in the sketch. Should the papers at any time refuse to move freely, it may be necessary to alter the adjustment between these rolls to see that they have not become sticky by contact with the bromide surface, or even to cover the driving-roll with a piece of thin but roughish paper. If moisture is suspected as being the cause of a stickiness of the bromide a saucer of calcium chloride may be placed in the clock-box. The most convenient form in which to use this substance is as cake mixed with asbestos. Every week this can be dried over a strong fire.

Calcium chloride, or other desiccating agents, must not be introduced in the instrument-case, for if they are a circulation of air is set up, and the boom swings to and fro, giving records which have often been called earth-tremors. For earthquake work the driving-roll must be adjusted in its outermost position, when it will turn once per hour. In its inner position it turns once in twelve hours, when it may be used, for example, for studying the diurnal wave.

The Watch.—This must be compared fairly often with a standard timekeeper, and its rate noted. It is particularly important that the time at which its hour-hand commences and ends its eclipse over the slit in the clock-box be noted, as it is from these markings that the times of earth disturbances are measured. This can be done either by watching the hour-hand of the watch by looking down the tube down which the mirror reflects light, or by watching the same when the clock-box is taken out of the instrument-case.

Developing, fixing, and copying the Film.—The films, which are 25 feet in length, are developed once a week. The developer employed has been chosen, because the same solutions may be used for several successive developments. The stock is kept as two separate solutions, made up as follows :—

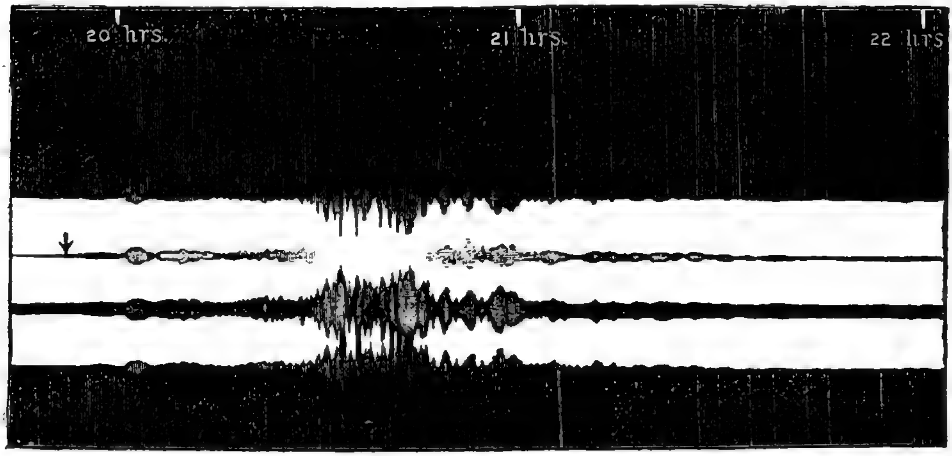
1st Solution.	Sulphate of soda,	1 oz.	or 1 part by weight.
	Carbonate of potash,	$\frac{1}{2}$ oz.	or $\frac{1}{2}$ " " "
	Bromide of potash,	$\frac{1}{40}$ oz. (10 grs.)	or $\frac{1}{40}$ " " "
	Water,	5 oz.	or 5 " " "
2nd Solution.	Metol,	$\frac{1}{6}$ oz. (75 grs.)	or $\frac{1}{6}$ " " "
	Water,	5 oz.	or 5 " " "

For use one ounce of each of these solutions is to be taken and mixed with about 24 ounces of water, and the whole is then poured into the developing-tray.

The film is doubled backwards and forwards in this solution, and the tray kept agitated until the development takes place, when the solution is poured off into a bottle to be kept until the following week. After the second time of use it may be strengthened with half an ounce of each of the above two solutions, when it will last two weeks longer. It is then thrown away. The next operation is to pour water once or twice into the developing-tray, and to rinse the film, after which it is dragged bodily over the end of the tray into a second tray containing a strong solution of hyposulphite of soda (1 hypo and about 4 water). Whilst in this solution the folds of the film are one by one gently opened to allow the hypo

to penetrate. After 10 or 15 minutes, when, by examination of the back of the film, all trace of yellow colour in the film is seen to have disappeared, the hypo is poured back to its bottle and the film is thoroughly washed for at least 15 minutes in several changes of clean water. The

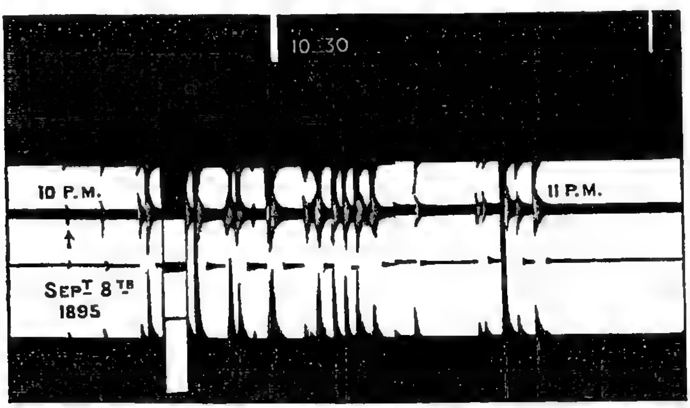
FIG. 2.—Japan Earthquake; Carisbrooke Castle Record.



hypo may be used perhaps twenty times until it has become dirty and ceases to have a saline taste.

The film in its tray of water is then placed on a plank or flat floor. One end of the film is pulled out of the tray and placed face upwards on

FIG. 3.—Displacements on September 10.



the plank or floor, after which the tray is drawn backwards and the film runs out and is left to dry.

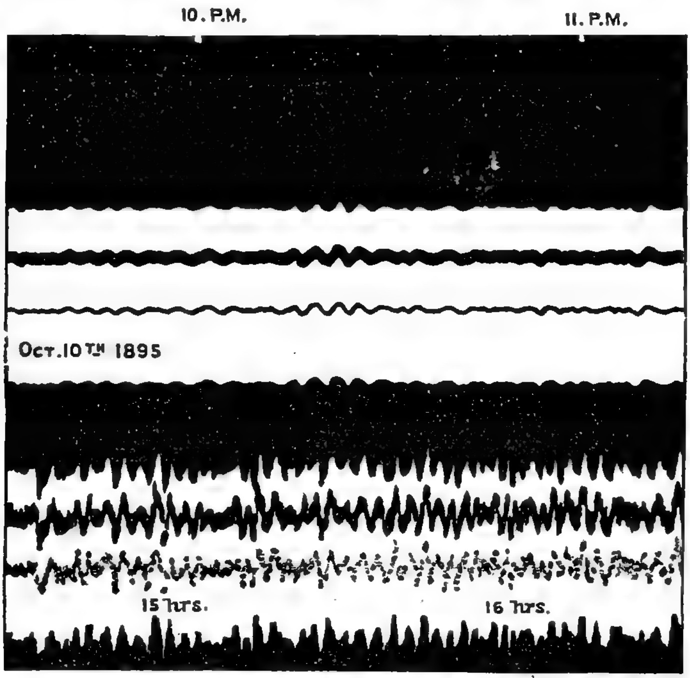
Any particular portion of a film may be reproduced by tracing on tracing-paper, or by photographical printing. For the latter process place the film with its back on a piece of glass or the glass face of a printing frame. A piece of bromide paper is placed with its sensitive surface in contact with the film, and over this a strip of wood or the back of the printing frame, when the whole four are clamped together with springs, clips, or indiarubber bands.

This is held up to the light of an oil lamp or an ordinary gas-burner at a distance of 30 inches for 3 to 10 seconds. Next it is developed in a little fresh but dilute developer. If the developer appears too strong, add water and a few drops of a 10 per cent. solution of bromide of potassium. Too long exposure causes the parts which should be white to become grey. A weak acid bath (citric acid 1 part in 40 of water) tends to remove stains. In warm climates a saturated alum bath may be used. If blisters appear weaken the hypo-bath.

Although photographic reproduction is here referred to, reproduction by tracing is quicker and usually sufficient.

The Photograms.—When the pendulum is at rest the photogram consists of two straight lines, one of which is thin and the other thick, like

FIG. 4.—Commencement and Growth of a Tremor Storm.



those shown over a distance of about a quarter of an inch on the left-hand side of fig. 2 ('British Association Report,' 1896, fig. 19, p. 229,[1]) which is the diagram of an earthquake recorded at Carisbrooke Castle, in the Isle of Wight, but which had its origin in Japan. The reason that two spots of light are used is that for slow movements the fine line gives the best definition, but for rapid movements the light passing through the fine slit is not sufficient to produce an impression on the photographic surface, and therefore, as in the middle of the figure, we have to rely on the image from the large spot.

Because the watch makes its eclipses at the half-hour the intervals marked as 20 hours, 21 hours, and 22 hours are read as 20·5 hours, 21·5 hours, and 22·5 hours, and then corrected from the known rate of the watch and the observed time of the eclipses. What is chiefly required

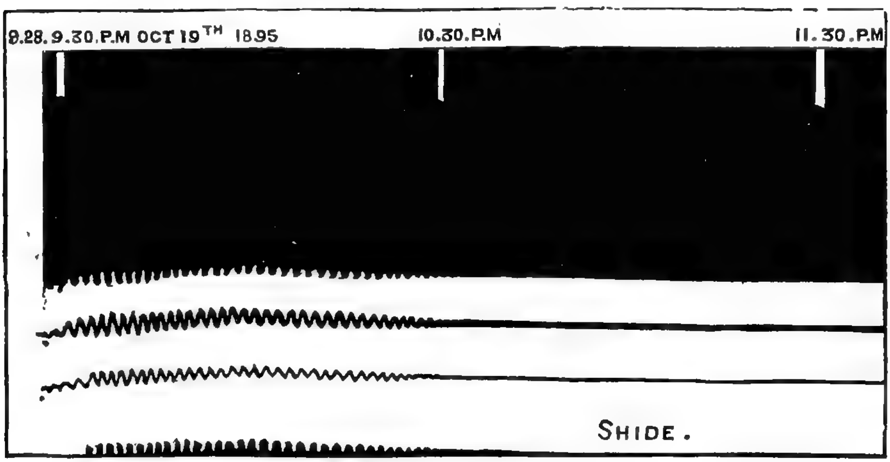
[1] This figure, like the others, having been reproduced from a wood block, is not so clear as the original.

from such a diagram is the Greenwich mean time of the commencement of the preliminary tremors which is near the small arrow, the commencement of decided motion, and the duration of the disturbance. After this, notes may be made of the number of maxima displacements.

Such notes, together with a tracing or photographic reproduction of the diagram, should be sent to the Seismological Committee, British Association, Burlington House, London, W.

In many instances the preliminary tremors, which in the illustration continue over an interval of 34 minutes, may only continue over 5 or 10 minutes, and their duration appears to be connected with the distance at which the disturbance originated. The cause of sudden displacements without preliminary tremors like those shown in fig. 3 ('British Association Report,' 1896, fig. 2, p. 190) is at present unknown. They are rare, and may be due to subsidence beneath the supporting pier. In a dark room, and especially in a warm climate, when removing the clock-box, it is quite possible that now and then a minute spider may find its way

FIG. 5.—Pulsations at Shide.



into the case. If when moving this box the boom is not set in motion, the existence of the work of such an intruder may be suspected, and it and its web must be removed. Such troubles are, however, very rare.

A photogram commencing with intermittent long-period movements, like those shown in the upper part of fig. 4 ('British Association Report,' 1896, p. 200), and increasing until they resemble its lower portion, indicates that the boom has been swinging from side to side under the influence of air currents established inside the case. Such movements, which have been called *earth-tremors* and *microseismic storms*, are at times extremely regular in their character. These latter, with periods of 2 or 3 minutes, are called pulsations (fig. 5. See 'British Association Report,' 1896, fig. 6, p. 201). These movements are frequent during the winter months, and especially at night.

Although they form an interesting study, because they may often eclipse the record of an earthquake, it is necessary that they should be

destroyed or avoided. Often they may be destroyed by giving the room in which they are situated a copious and even draughty ventilation. If this does not succeed, the instrument must have a new installation. They are seldom met with in a badly constructed hut or beneath a tent.

Examples of Daily Records.

Date	Light out	Light in	Error of Eclipse Watch	Remarks
1897	h. m.	h. m.	sec.	
Feb. 12	10.41	10.55	−33	Period 18 s. Sensibility 1° = 5 mm. Reset 25° to 30°.
	21.55	21.57		
„ 13	10.30	10.50	−39	Eclipsed light from 10.55 to 10.56, as shown by the eclipse watch.
	21.38	21.40		

&c., &c., &c., up to the end of the week.

From the above records it will be observed that the light has been removed or extinguished twice a day. The times at which this is done is very roughly noted with a pocket-watch. In the morning the lamp is refilled, the eclipse watch wound, and, if necessary, the pendulum, which may have wandered too much on one side, is reset.

The error of the eclipse watch must, relatively to some standard time, be noted accurately. For meaning of 'period' and 'sensibility,' which only need be determined once a week, and which can be expressed in seconds of arc, see pp. 139, 140.

From the mark shown on the developed film when the light is eclipsed the time at which the watch commences to make an eclipse mark can be calculated. These times, as shown on the dial of the eclipse watch, should always be the same, and therefore in order to guard against accident they are only made occasionally. By adding or subtracting the error of the eclipse watch to the time at which an eclipse mark has been made, the exact G.M.T. of this mark is obtained, from which any particular phase of an earth movement may be computed.

Weekly Report.

At the end of the week a report is drawn up of the records, the form of which largely depends upon the movements which have been recorded.

All times must be expressed in Greenwich mean time (civil), the day commencing after 24 hours or midnight. Thus the ordinary notation of June 16, 1.30 A.M., and June 16, 11.30 P.M., becomes June 16, 1.30, and June 16, 23.30.

The most important elements to be noted about an earthquake disturbance are :—

1. The exact time at which preliminary tremors commence.
2. The duration of those tremors.

3. The times at which various maxima of motion are attained, and the tilting they represent expressed in seconds of arc.

4. The total duration of the disturbance.

5. A tracing of the photogram.

IV. *Observations at Carisbrooke Castle and Shide.* *By* JOHN MILNE, *F.R.S., F.G.S.*

In the report for last year it was stated that at about the end of June, through the kindness of Mr. A. Harbottle Estcourt, Deputy-Governor of the Isle of Wight, I had been enabled to establish a second horizontal pendulum at Carisbrooke Castle, and a description of this installation, together with that at Shide, was given in some detail. The object of the second installation was to see how far the records of two similar instruments at some distance apart coincided in character. The Shide records, as already reported upon, consist of movements due to *earthquakes* which have originated at some distance—*displacements*, which show that the boom of the instrument has suddenly been caused to swing or change its zero points ; *tremors*, which are irregular swingings of the boom extending over many hours or several days ; *pulsations*, which are regular back and forth movements of a pendulum, which movements have periods of two or three minutes ; *diurnal waves* and *seasonal wanderings.*

In the following report these movements will be discussed in the order in which they are here mentioned, the Carisbrooke records being taken first.

The Carisbrooke Records.

The Carisbrooke records were obtained between June 16 and August 31, 1896. Because the journey to Carisbrooke and back entailed a walk of four miles, it was only visited once every twenty-four hours. For this reason, together with the fact that the clockwork arrangement often failed to drive the photographic paper—an imperfection which has since been remedied—there were very many interruptions in the continuity of the records. Notwithstanding this, a sufficient number were obtained to compare with corresponding records at Shide, and to indicate the character of Carisbrooke as an observing station.

The *earthquakes* recorded were as follows :—

July 5.—Four exceedingly small, elastic switchings of the boom, the first at 3 hrs. 6 mins. 47 secs., and the last at 3 hrs. 44 mins. 7 secs.

July 21.—At 7 hrs. 3 mins. 53 secs. there was a small elastic disturbance with 5 maxima.

August 30.—A very heavy disturbance (see fig. 2), corresponding in time, points of maxima, and other detail with the Shide record, No. 36. This earthquake had its origin in Japan.

The first two records, which have amplitudes of ·5 to 1 mm., do not correspond with records at Shide, whilst there are similar minute disturbances recorded at Shide which are not visible on the Carisbrooke photograms. The conclusion, for the present, at least, is that these small tremors, which suggest an elastic switching of the end of the boom, are very often of local origin, whilst earthquake movements of a pronounced character are recorded in a similar manner at both stations. The reason that no record was obtained at Carisbrooke on August 26 (No. 35 in the Shide list) was because on that day the recording apparatus was not in operation. The days of such interruptions are indicated on the general list of disturbances, pp. 147, 148.

The *sudden displacements or disturbances* noted at Carisbrooke are given on the list just mentioned. As compared with Shide they are very few in number, and at the two stations there was no agreement in the times at which they took place.

Tremors and *pulsations*, which I am inclined to regard as being due to slow and fairly regular air currents within the covering cases of instrument, were practically absent at Carisbrooke.

Because the observation of the *diurnal wave* and longer-period movements require an adjustment of the clockwork, so that it runs at a slow speed, these were not observed. Inasmuch as readings taken of the position of the end of the boom showed but little change, it is probable that they are small.

Because the latter three classes of movement were frequent at Shide, whilst they were practically absent at Carisbrooke, it is evident that the latter station is the better site for the observation of earthquakes.

Displacements observed at Carisbrooke Castle and Shide in 1896.

l. d. = large displacement; m. d. = moderate displacement; s. d. = small displacement.

Date	Shide				Carisbrooke			
	Time			Character	Time			Character
	H.	M.	S.		H.	M.	S.	
June 16	23	40	0	l. d.		—		—
„ 17	6	29	50	s. d.		—		—
„ 21	6	38	36	s. d.		—		—
„ „	6	55	48	s. d.		—		—
„ „	21	38	36	s. d.		—		—
„ 22	7	4	24	l. d.	5	51	40	l. d.
„ „	18	45	12	l. d.		—		—
„ 23	2	13	5	s. d.	5	34	32	l. d.
„ „	4	33	44	s. d.	19	13	12	s. d.
„ 25	10	18	16	m. d.	Not working			—
„ 26	10	6	26	s. d.	„	„		—
„ 27	6	28	26	s. d.	7	22	21	s. d.
„ „	8	16	0	s. d.	7	32	31	s. d.
„ „	13	31	26	s. d.	7	47	31	l. d.
„ „	17	31	0	s. d.	Not working			—
„ 28	2	53	24	s. d.	„	„		—
„ „	6	47	4	s. d.		—		—
„ „	7	4	16	l. d.		—		—
„ 29	10	8	50	l. d.	Not working			—
July 2	18	51	29	l. d.	„	„		—
„ 3	10	26	47	m. d.	„	„		—
„ „	21	10	41	s. d.	„	„		—
„ „	21	26	41	s. d.	„	„		—
„ 4	19	53	6	s. d.	„	„		—
„ 5	9	47	6	s. d.		—		—
„ 7	9	26	20	l. d.	Not working			—
„ 9	5	43	11	s. d.	„	„		—
„ 12	1	36	40	l. d.	„	„		—
„ „	7	45	40	l. d.	„	„		—
„ 13	0	41	17	l. d.	„	„		—
„ „	18	41	17	l. d.	„	„		—
„ 14	1	3	51	s. d.	„	„		—
„ 17	5	12	42	l. d.	Not working			—
„ 21	5	26	25	l. d.		—		—
„ „	10	8	48	s. d.		—		—

DISPLACEMENTS OBSERVED AT CARISBROOKE CASTLE AND SHIDE IN 1896—*cont.*

Date	Shide				Carisbrooke			
	Time			Character	Time			Character
July 24	2	20	13	m. d.	—			—
" "	8	34	45	s. d.	—			—
" "	10	33	17	s. d.	—			—
" "	13	21	41	s. d.	—			—
" "	19	59	41	s. d.	—			—
" "	21	39	9	s. d.	—			—
" 25	2	16	18	m. d.	—			—
" "	9	39	12	l. d.	12	30	10	l. d.
" 26	13	22	2	l. d.	—			—
" 27	7	13	3	l. d.	—			—
" "	10	10	27	s. d.	—			—
" "	21	40	21	m. d.	—			—
" 29	2	31	33	m. d.	—			—
" "	10	7	43	s. d.	—			—
" "	14	29	55	l. d.	—			—
" 30	4	14	39	s. d.	2	8	47	—
" "	10	17	15	s. d.	19	30	7	l. d.
" 31	2	14	33	s. d.	—			—
" "	10	21	27	s. d.	—			—
" "	18	47	3	s. d.	—			—
Aug. 1	2	2	56	s. d.	—			—
" "	18	54	6	s. d.	—			—
" 2	18	54	19	s. d.	—			—
" 3	Not working			—	5	34	0	m. d.
" 4 to 11	—			—	—			—
" 12	4	35	36	l. d.	—			—
" "	10	31	56	l. d.	—			—
" 13	2	15	26	s. d.	—			—
" 14	15	54	16	l. d.	—			—
" 15	1	57	46	s. d.	—			—
" "	13	58	58	s. d.	—			—
" "	15	32	44	l. d.	—			—
" "	15	49	0	l. d.	—			—
" 16	9	10	4	l. d.	—			—
" "	9	13	22	l. d.	—			—
" "	21	38	12	l. d.	—			—
" 17, 18	—			—	—			—
" 19	1	55	32	l. d.	—			—
" "	17	19	54	l. d.	16	47	48	l. d.
" 20	2	26	41	l. d.	—			—
" "	18	59	39	l. d.	—			—
" "	21	9	41	l. d.	20	7	50	m. d.
" 21	9	36	37	s. d.	—			—
" 23	22	26	22	l. d.	8	1	8	l. d.
" "	—			—	11	51	48	l. d.
" 24	—			—	4	57	6	—
" 28	2	7	27	s. d.	—			—
" "	5	50	45	l. d.	—			—
" "	10	22	27	l. d.	—			—
" 30	7	9	16	s. d.	—			—
" "	22	29	34	l. d.	—			—

Records with an Earthquake-like Character observed at Shide, 1896–97.

For the commencement of the Shide records (August 19, 1895, to March 22, 1896) the reader is referred to 'Report of the British Association' for 1896, p. 191, in which shocks and displacements are included in

one list. The following list only includes movements which have an earthquake-like character; but as it is possible that certain small displacements may have been mistaken for earthquakes when examining the list, the following explanatory notes will make it easy to identify records which are doubtful.

The sign >, or a series of such signs, indicates a small movement, or a series of small movements, with an amplitude of about 1 mm., which *commenced suddenly* and ended gradually. It is quite possible that some of them, at least, may be due to some local cause—as, for example, a slight settlement beneath the pier on which the instrument is rested—and therefore are not earthquakes. The sign ⌒, or a series of such signs, indicates a very small movement, or series of movements, which *commenced gradually* and ended gradually. Such movements have a true earthquake character; but because I have no record where they were nearly simultaneously recorded at Carisbrooke, they must, in many instances, at least, be of local origin.

Disturbances which are 'moderate,' or disturbances which have amplitudes exceeding 2 mm., if these commence gently it may be assumed that they are of earthquake origin.

All large disturbances commencing with decided preliminary tremors are certainly earthquake effects. Those to which an asterisk is attached are described at the end of the list in more or less detail. The materials for their description have been derived from my own observations, observations made in Japan, communications from various observers in Europe and Great Britain, the 'Bolletino della Società Sismologica Italiana,' the columns of 'Nature,' and other sources.

Earthquakes observed at Shide, Isle of Wight, 1896–97. (*All times are given in Greenwich mean astronomical time. Midday or noon* = 0 *or* 24 *hours.*)

No.	Date	Hour of commencement, G.M.T.	Remarks	Observed also at			
				Ischia	Potsdam	Nicolaiew	Edinburgh, from middle of August
			1896.				
		H. M. S.					
1*	June 14	22 30 0	Large ⌒ >	—	—	—	
2	„ 22	10 6 26	Small >				
3	„ 24	9 47 56	„ „				
4	„ 27	13 8 35	„ „				
5		13 58 59	„ ⌒				
6		14 30 19	„ >				
7	„ 28	9 27 17	„ „				
8*	„ 29	9 2 26 } 9 24 45 }	Four maxima	—		=	
9	„ 30	10 6 0	Small ⌒				
10		18 21 57	„ >				
11	July 1	9 40 1	„				
12		10 26 51	„				
13		11 51 13	„				
14		12 36 53	„				
15	„ 2	8 04 22	„ >				

EARTHQUAKES OBSERVED AT SHIDE—*continued.*

No.	Date	Hour of commencement, G M.T.	Remarks	Observed also at: Ischia	Potsdam	Nicolaiew	Edinburgh, from middle of August
		H. M. S.					
16		10 11 31	Moderate, commences gently				
17*		18 51 29	,, ,, ,, >				
18	July 8	14 54 14	Small ⌒⌒⌒⌒				
19		17 46 11	,, ⌒⌒				
20	,, 11	10 8 49	Moderate. Four maxima				
21	,, 16	8 12 53	Small				
22	,, 17	19 2 40	Moderate >				
23	,, 18	0 9 48	Small >				
24		18 53 14	,, ⌒				
25		23 52 50	Small. Several maxima >				
26	,, 30	11 25 0 } 13 25 0 }	,, ,, ,, ⌒				
27	,, 31	23 25 0	,, ,, ,, ⌒				
28	Aug. 12	23 53 36	Very small ⌒				
29	,, 14	10 19 50	Small ⌒				
30		11 27 16	,, ?,,				
31	,, 23	5 38 52	,, ,,				
32	,, 25	4 27 31	,, ,, ...				
33		5 3 21	,, ,,				
34		12 33 15	,, >				
35*	,, 26	11 23 48	Large preliminary tremors last 1m. 16s. Duration 50m.	—	—	—	—
36*	,, 30	20 23 6	Large preliminary tremors last 34m. Duration nearly 3h.	—	—	—	
37	Sept. 10	0 57 51	Small ⌒⌒				
38		17 36 23	,, >				
39	,, 12	17 44 32	Small preliminary tremors last 5m. 44s. ⌒		—	—	
40		18 52 29	Small ⌒				
41	,, 14	0 51 39	,, > ⌒ >		—		
42	,, 20	4 20 50	,, ⌒				
43		4 29 10	,, >				
44		4 37 21	,, ,,				
45		4 59 10	,, ,, ...				—
46		16 14 48	Moderate				
47*	,, 21	17 2 2	Total duration—35m. 50s. ⌒⌒⌒	—	—	—	—
48*	,, 23	11 59 50	Moderate preliminary tremors 7m. 10s. Duration—28m. 40s.	—	-	—	—
49*	,, 24	10 39 20					
50	,, ,,	11 40 24	Duration—34m. 5s. ⌒ . .			—	—
51	Oct. 6	12 51 27	Twelve separated maxima, ending at 14h. 9m. 18s. > > > &c.	—			
52	,, 13	10 17 52	Small >				
53	,, 14	7 41 25	Moderate				
54	,, 25	5 57 26	Small >				
55	,, 27	10 15 10	> followed at 10h. 28m. 50s. by ⌒⌒. Duration—21m.				
56*	,, 31*	17 18 2	Large preliminary tremors last 13m. 51s. Total duration—3h. to 4h.	—	—	—	
57	Nov. 2	4 9 56	Small >			—	—?

EARTHQUAKES OBSERVED AT SHIDE—*continued.*

No.	Date	Hour of commencement, G.M.T.	Remarks	Observed also at: Ischia	Potsdam	Nicolaiew	Edinburgh, from middle of August
		H. M. S.					
58		8 14 58	Small >				
59		10 20 42	" "				
60	Nov. 4	5 1 46	" > >				
61		6 27 41	" >				
62		8 57 47	Moderate				
63		10 11 9	Small ⌒				
64	" 5	3 40 19	" >				
65		6 52 19	" "				
66		6 69 35	" "				
67*		9 44 58	Large preliminary tremors last 15m. 46s. Total duration—55m.	—		—	
68	" 26	9 27 29	Moderate ⌒				
69	Dec. 1	21 55 33	End at 23h. 31m. 20s. ⌒⌒⌒				
70	" 4	8 7 50	Small ⌒⌒⌒⌒				—
71		8 43 3	" > > >				
72		9 33 18	" > > > ⌒				
73*	" 16	14.30 to 22.0	A series of small tremors. Maxima 17h. 30m.				
74	" 18	13 12 11					
		16.28 to 18.28	Small tremors				
75	" 26	11.30 to 22.30	⌒⌒⌒				
			1897.				
76	Jan. 3	2 27 3	Preliminary tremors last 8m. 31s. Maxima motion at 2h. 36m. 53s.				
77	" 8	22 39 3	Maxima at 22h. 40m. 23s. ⌒			—	
78	" 16	10.8 to 10.29	Small ⌒⌒⌒		—		
79		23 52 47	" ⌒				
80	" 17	9 16 2	" ⌒⌒				
81	" 18	11.30 to 16.30	Tremors with maxima at 14h. 3m. 50s.				
82	" 23	9 43 20	Small ⌒				
83*	Feb. 6	19 59 3	Tremors last 26m. 40s. Total duration—1h. 6m.	—	=	—	—
84	" 7	11 55 7	Small ⌒		—		
85	" 12	14 8 11	Tremors last 3m. 50s. Duration—13m. 20s.		—	—	
86	" 13	3 23 36	Moderate. Duration—9m. 20s. ⌒				
87	" 16	12.30 to 22.30	Small ⌒⌒⌒				—?
88	" 19	12 17 47	Four moderate maxima, ending 13h. 16m. 27s. From 6h. to 10h. not working.	—	=?	—?	—
89	Mar. 1	14 40 14	Moderate >			—	
90	" 2	14 49 34	" >				
91		9 48 11	Small ⌒⌒⌒				
92	" 13	22 46 56	" ⌒				
93	" 15	19 36 27	Moderate. Total duration—29m. 20s.			—	
94	" 16	4 49 49	Small ⌒				
95	" 18	1 37 26	" "				

Fig. 6.—August 26, 1896.

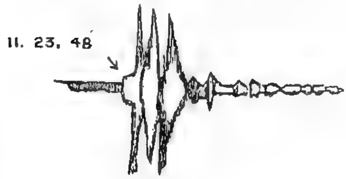


Fig. 7.—September 12, 1896.

Fig. 8.—September 21, 1896.

Fig. 9.—September 23, 1896.

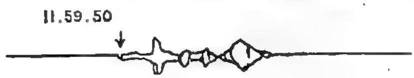


Fig. 10.—October 31, 1896.

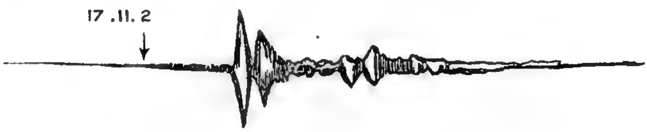


Fig. 11.—November 5, 1896.

Fig. 12.

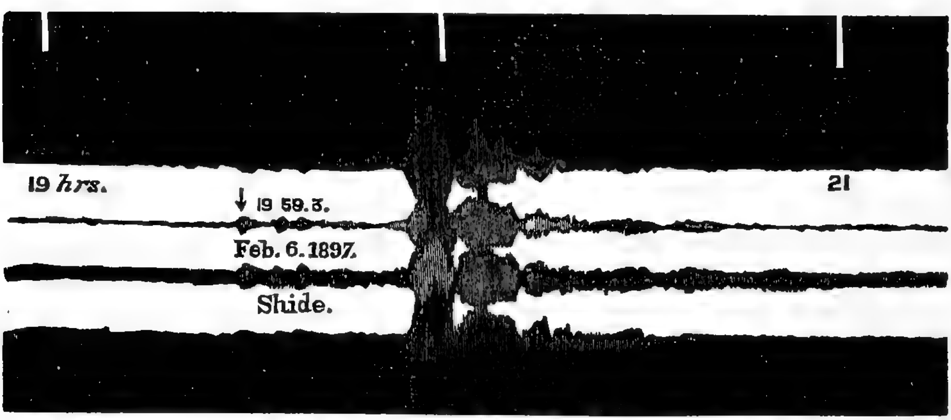
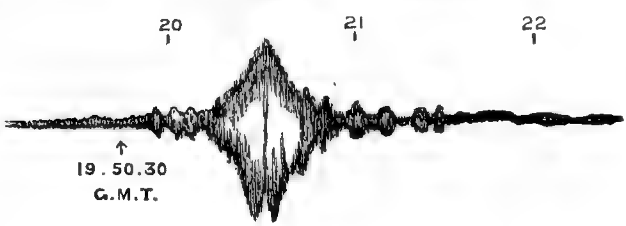


Fig. 13.—Potsdam, February 6, 1897.



V. *Earthquake Records from Japan and other places.*
By JOHN MILNE, *F.R.S., F.G.S.*

Earthquake No. 1.—*On the Sea-waves and Earthquakes of June* 15, 1896, *in North Japan.*

(Unless otherwise stated, Japan mean time, or G.M.T. + 9 hours, is here used.)

The sea-waves which at about 8 P.M. on June 15, 1896, invaded the north-eastern coast of Nippon were as destructive to life as those which accompanied the well-known eruption on August 26, 1883, of Krakatoa, whilst one of the shocks by which they were preceded was of such severity that it was clearly recorded in Europe, and in every probability caused a disturbance over the entire surface of the globe.

The magnitude of this disturbance, and the sub-oceanic changes by which it was probably accompanied, make it well worthy of record. The sources from which the following notes bearing upon this catastrophe have been derived are various. Amongst the more important are translations from the writings of Professor Kochibe and other officers of the Geological Survey of Japan; extracts from Japanese newspapers; the records of the Central Observatory in Tokio, and those from a large number of other observatories at which disturbances were recorded; and, lastly, the writer's personal knowledge of the devastated districts, and experiences connected with sea-waves and earthquakes which have previously occurred in the same locality.

A full discussion of the phenomena which accompanied this great catastrophe might be divided under two heads, one containing an account of the earthquakes which were recorded, and the other an account of the sea-waves.

Although one or two houses were destroyed by earthquake movement in Yamada, the greatest destruction was that caused by sea-waves, of which the first three were the greatest. The places which suffered most were Kamaishi, Yoshiyama, and neighbouring towns and villages lying in the inlets of the cliff-bound coasts of Rikuzen and Rikuchu, on the N.E. coast of Nippon. Fishermen twenty or twenty-five miles off shore did not observe anything unusual.

List 1.—*Shocks recorded in Japan on June* 15 *and* 16, 1896.

Time (M.J.T.)	Duration	Direction	Remarks	Intensity
H. M. S.				
7 32 30 P.M.	5 m.	E.N.E. W.S.W.	A few houses damaged	slight
7 53 30	The high tide came, and continual shocks were felt.			
8 2 35				
8 23 15				
8 33 10				
8 59 0				
9 31 30				
9 34 5				
9 45 40				
9 50 10				
10 32 10				
11 22 0				
11 33 15				

The first list is that of thirteen shocks noted on June 15 at the Observatory in Miyako, a place lying to the north of Kamaishi and Yamada, where the sea-waves were felt with great force.

The following is a list of shocks noted at observatories in various parts of Japan. The Tokio shocks will also be found in the list of records from the Meteorological Observatory in that city (pp. 135–6, Nos. 1,710 to 1,740). Of these latter, it will be noted that there were only three of marked intensity, and it does not seem that these were connected with the occurrence of the first sea-waves.

List 2.—Earthquakes noted at Observatories in Northern Japan in 1896.

Date	Japan Mean Time	Character of Shock	Place
	H. M. S.		
June 15	5 43 15 P.M.	slight	Fukuoka.
,,	5 44 0	,,	Choshi.
,,	5 44 43	,,	Tokio.
,,	5 47 13	,,	Kofu.
,,	7 33 20	weak, slow	Awomori.
,,	7 34 0	slight, slow	Fukushima.
,,	7 34 14	weak, slow	Tokio.
,,	7 30 20	slight, slow	Nemuro.
,,	7 34 30	weak	Hakodate.
,,	7 34 45	slight, slow	Sakai.
,,	7 35 0	weak, slow	Utsunomiya.
,,	7 36 21	,,	Kofu.
,,	7 39 0	slight	Yamagata.
,,	7 45 57	,,	Fukushima.
,,	7 48 43	,,	,,
,,	7 52 0	,,	,,
,,	7 57 0	slight, slow	,,
,,	8 3 0	,,	Awomori.
,,	8 7 50	slight	Yamagata.
,,	8 5 36	weak, slow	Kofu.
,,	8 10 26	slight	Fukushima.
,,	8 21 20	,,	Awomori.
,,	8 27 20	,,	Fukushima.
,,	8 32 45	,,	Awomori.
,,	8 33 53	,,	Tokio
,,	8 38 10	,,	Awomori.
,,	8 59 23	slight, slow	,,
,,	8 59 35	slight	Fukushima.
,,	9 0 38	,,	Tokio.
,,	9 2 31	,,	,,
,,	9 3 45	,,	Kofu.
,,	9 6 20	,,	Yamagata.
,,	9 11 37	,,	Fukushima.
,,	9 13 55	,,	Awomori.
,,	9 14 14	,,	Tokio.
,,	9 17 20	,,	Kofu.
,,	9 19 40	,,	Awomori.
,,	9 26 18	,,	Fukushima.
,,	9 27 35	,,	Tokio.
,,	9 27 52	,,	Awomori.
,,	9 32 0	,,	,,
,,	9 46 31	,,	,,
,,	9 46 57	,,	Fukushima.
,,	9 49 30	,,	Awomori.
,,	9 56 30	,,	,,
,,	9 56 39	,,	Tokio.
,,	9 59 52	,,	Kofu.

LIST 2—*continued.*

Date	Japan Mean Time	Character of Shock	Place
	H. M. S.		
June 15	10 2 0	slight	Yamagata.
"	10 9 25	"	Awomori.
"	10 32 36	"	"
"	11 19 7	"	"
"	11 30 18	"	"
"	11 56 30	"	"
June 16	0 34 51 A.M.	"	"
"	0 48 45	"	"
"	0 49 0	weak, slow	Ishinomaki.
"	0 49 48	slight	Tokio.
"	0 51 8	"	Kofu.
"	1 5 22	"	Tokio.
"	1 5 45	"	Awomori.
"	1 25 33	"	"
"	1 32 14	"	Tokio.
"	1 47 2	"	"
"	1 47 36	"	Kofu.
"	1 52 0	"	Yamagata.
"	1 57 53	"	Awomori.
"	2 39 0	"	"
"	3 16 50	weak, slow	Utsunomiya.
"	4 15 20	slight	Fukushima.
"	4 16 30	weak, quick	Tokio.
"	4 16 35	slight, slow	Sakai.
"	4 17 0	slight	Awomori.
"	4 18 5	"	Niigata. Clocks stopped.
"	4 18 28	weak, slow	Kofu.
"	4 22 0	slight	Yamagata.
"	5 1 9	"	Tokio.
"	6 1 48	"	Awomori.
"	6 40 1	"	Tokio.
"	7 17 16	"	Awomori.
"	7 51 12	"	"
"	8 0 49	weak	"
"	8 0 50	slight	Fukushima.
"	8 1 14	weak, quick	Tokio.
"	8 3 4	weak	Kofu.
"	8 6 0	slight	Yamagata.
"	8 14 17	"	Awomori.
"	8 14 45	"	Fukushima.
"	8 15 20	"	Tokio.
"	8 16 29	"	"
"	8 20 20	"	Yamagata.
"	8 22 57 A.M.	"	Awomori.
"	8 58 29	"	Hikone.
"	9 30 35	"	Awomori.
"	9 32 1	"	Tokio.
"	9 46 11	"	Awomori.
"	9 47 11	"	Tokio.
"	10 1 7	"	Hikone.
"	0 25 26 P.M.	"	Fukushima.
"	0 26 12	"	Tokio.
"	1 15 3	"	"
"	1 28 38	"	"
"	1 29 48	"	"
"	3 11 31	"	"

Nearly all these disturbances were only felt in the northern part of Nippon. Thirty-three were noted in Awomori, 26 were recorded in Tokio, 15 in Fukushima, 10 in Kofu, 7 in Yamagata, and 2 in Sakai. The two shocks recorded at Hikone, which is 450 miles distant from Miyako, were probably of local origin. The fact that the Miyako earthquakes were only sufficient to disturb seismographs in North Japan, whilst the effect of one at least of the series was recorded in Europe, indicates that the origin of these movements was far from land. Had it been a few hundred miles still farther off shore it seems likely that ordinary seismographs, recording on smoked-glass surfaces, would have failed to have given any indications that submarine disturbances had taken place. We have, therefore, here an illustration of the necessity of using horizontal pendulums with photographic recording apparatus, or the equivalent of such instruments, if we desire to study sub-oceanic movements or the effects produced by earthquakes which have originated at great distances.

Sea-waves.—Coast of Rikuzen and Rikuchu (Home Department Report).—First high water at 8.25 P.M. Altogether ten large waves, the first three being at intervals of six minutes.

Miyako.—First high water, 8.20 P.M. Sea retreated about 7.15 P.M.; sea rose about 8.0 and 8.7 P.M. This last tide or wave rose 15 feet, and people and houses were carried away. The tide rose six times.

Tawoi mura.—Sea retreated 1,800 feet.

Hakodate (Yesso).—Tides rose and fell from 10 P.M. on the 15th until 10 A.M. on the 16th. At 4 P.M. on the 16th quiet was restored.

Mororan (Yesso).—High tide at 8 P.M.

Tokachi and Moyori (Yesso).—At 11 P.M. the tide was 10 feet lower than usual. It rose four or five times to heights of 60 or 100 feet.

Kinkazan.—Tide gauge showed changes of 7 or 8 feet.

Bonin Ids.—Tide rose 3 or 4 feet.

Hawaii.—In fourteen hours fourteen tides were noticed, commencing at 7.38 P.M.

Sounds.—Sounds like thunder or the report of a heavy gun were heard at many places, at Miyako before 8 P.M.; at Kitsugawa, in Miyagi Ken; at Tokachi and Moyori, in Yesso, &c.

Unusual Set of Ocean Currents.—Sweeping up the eastern coast of Japan is the great Black Stream, or Kuro Siwo, the strength of which, as indicated by the distance to which it is felt and its position with regard to the coast, is subject to seasonal variation. Along the inundated coast a warm current is felt from spring to autumn, whilst during the winter months the same shores experience a current that is cold. In 1896, spring passed, and yet the cold water hugged the shore, and the fishermen seeking bonito had to go farther than usual from land until they reached warmer waters.

Origin of the Disturbance.—Because the village of Taoi was destroyed by two great waves, one coming from the south and the other from the north, it has been assumed that at a distance of from five to eight miles off the village a submarine landslip had taken place, and the waters rushed inwards towards the scene of dislocation. Because places along 150 or 200 miles of the coast on which Taoi is situated were inundated at about the same time, as Professor Kochibe points out, it is clear that the origin of the convulsion was at a very much greater distance from the land than that just indicated.

Because the sea-waves were preceded by earthquakes it is evident

that at least one of the latter must have been accompanied by enormous dislocations in order to have produced the former.

These earthquakes, as recorded on land, were comparatively small, which, from what we know of the dissipation of earthquake energy as it radiates from its origins, indicates that the earth vibrations must have travelled *at least* 100 miles.

The *least* interval of time that we can give between the arrival of the vibratory wave and the sea-waves is that observed at Miyako, which is 21 minutes.

If we assume a mean depth for the ocean off the north-east coast of Nippon, along an easterly line, to the origin of the disturbance at 2,000 fathoms, then the distance from the land to the origin may be expressed

$$\sqrt{12000 \times g} \times 21 \times 60,$$

or about 130 geographical miles.

Again, if we assume v_2 to be the velocity of the sea-wave, which may be taken at 500 feet per second, this being a somewhat low observed velocity for earthquake sea-waves approaching this coast; v_1 the velocity of the vibratory waves, which over a short range has often been observed at 7,000 or 8,000 feet per second; and T the observed interval of time between the arrival of the two waves, then the distance of their origin from the coast is

$$\mathrm{T}.\frac{v_1 . v_2}{v_1 - v_2},$$

or in this case about 113 geographical miles.

If we make $v_2 = 600$ feet per second, the distance of the origin becomes about 140 geographical miles.

Because we have taken the least interval that can be assigned to the difference in the times of the arrival of the land and sea-waves, it may be concluded that the origin of the Japan disturbance of June 15 was along a submarine line at a distance of 120 to 140 geographical miles off the coast of North-east Nippon.

Such a locus is at a depth of 4,000 fathoms, and, so far as we know the sub-oceanic contours, exactly at the bottom of the Nippon slope, forming the western boundary of the Tuscarora Deep, a well-known origin for many large earthquakes (see map, fig. 14).

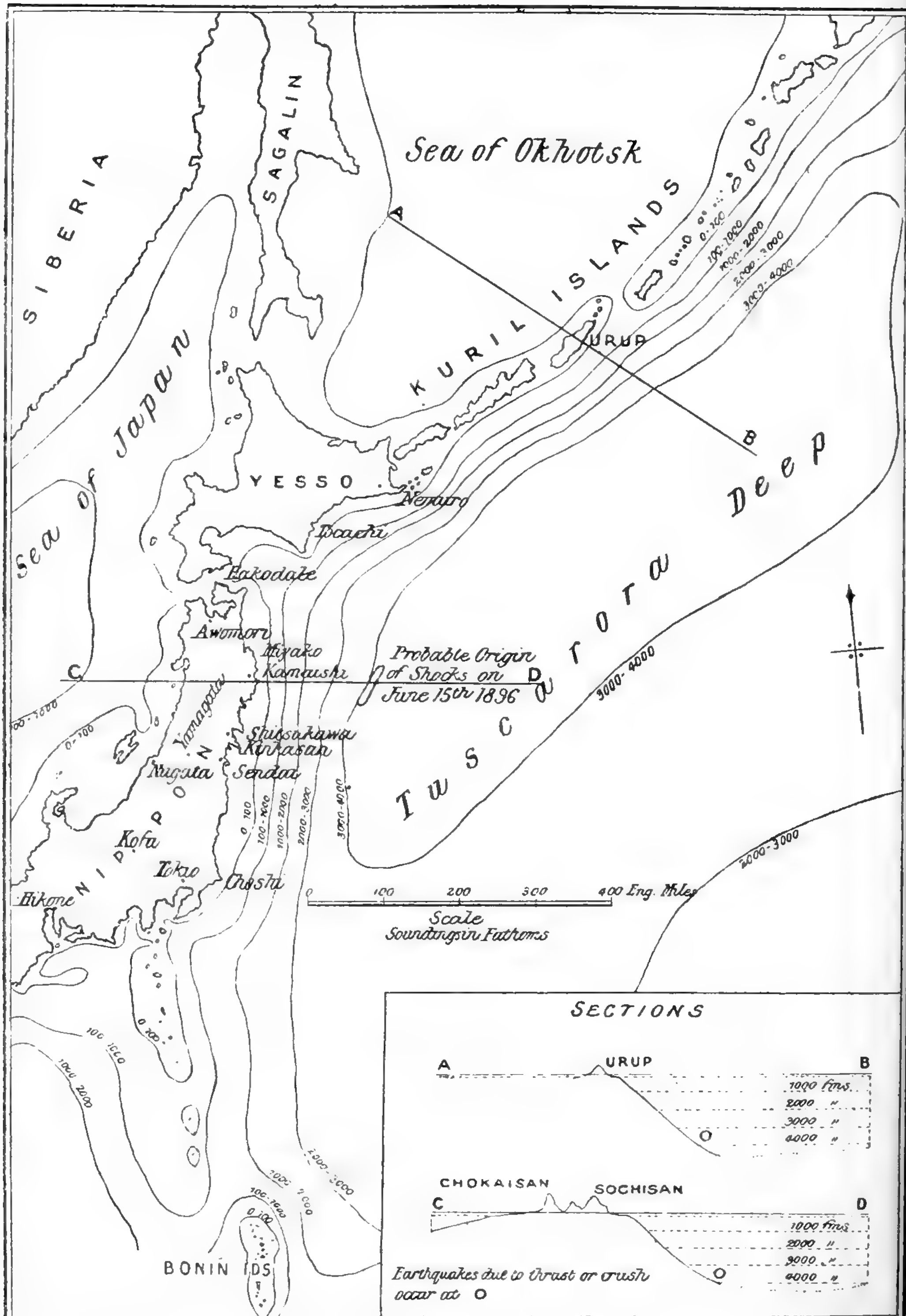
Although much evidence may be adduced to show that early in June 1896 the ocean currents were deranged in direction and intensity, the cause of the submarine dislocation was probably seismic.

Velocity of Propagation of Earth-waves.—Assuming the origin to lie 120 geographical miles east of Miyako, to which place it travelled at a rate of 8,000 feet per second, which fairly well accords with the velocity it travelled from the Miyako isoseist to Tokio, and velocities of propagation of similar earthquakes over short ranges, the time, within a few seconds, at which the earthquake occurred was, in G.M.T., June 14, 22h. 31m. 0s.

G.M.T.—Times at which Preliminary Tremors commenced in Europe.

	H.	M.	S.		M.	S.
Padua	22	46	57	Time to travel . .	15	57
Ischia	22	49	50	" . .	18	50
Rocca di Papa . .	22	56	18	" . .	25	18

FIG. 14.—Map to show submarine earthquake origins near Japan.



The last observation evidently refers to a phase of movement different from that of the first two, and therefore will not be further considered.

Padua . .	9,320 kms	Velocity . .	9·7 kms. per sec.
Ischia . .	9,749 „	„ . .	8·7 „ „

We should expect to have found these two velocities to have been nearly equal. Their mean value, or the probable rate at which motion was transmitted from Japan to Italy, was

9·2 kms. per sec. on an arc.
And about 8·3 „ „ „ on a chord.

The velocity of transmission to Tokio was about 3 kms. per second.

Earthquake No. 8 (Cyprus).[1]

A severe earthquake took place in Cyprus on June 29, at *about* 8h. 48m. 0s. Other records of this disturbance were as follows :—

	H.	M.	S.
1. Shide	9	2	26
2. Ischia	8	48	20
3. Rocca di Papa	8	48	27
4. Rome	8	48	35
5. Padua	8	49	0
6. Catania	8	50	30
7. Nicolaiew	8	47	0

The observations 2 to 7 clearly indicate a large error in the observation made near the origin in Cyprus. The only calculations of velocity which can therefore be made are on paths between the Nicolaiew isoseist and the first six places.

Places	Distance in Kms. from Cyprus	Distance in Kms. from the Nicolaiew Isoseist	Time of Transit from the Nicolaiew Isoseist (M. S.)	Velocity in Kms. per Sec.
Nicolaiew . .	1,332	—	—	—
Catania . .	1,684	352	3 30	1·7
Ischia . .	1,813	481	1 20	6·0
Rome . . .	1,998	666	1 31	7·3
Padua . .	2,192	860	2 0	7·1
Shide . . .	3,404	2,072	15 . 26	2·2

The first and last determinations may possibly refer to the maximum phases of motion, and the three intermediate ones to the velocity along a path at some depth beneath the surface.

We have here an illustration of high velocities of propagation, which we sometimes find between places each of which are at a distance from an epicentre.

Earthquake in Iceland, No. 35, 1896.

August 26, at about 10.30 P.M. in local time. Very severe shocks, originating in or near the Hekla ridge. Many landslides, four houses thrown down. One fissure on the Oelvus River, 6 miles long. New geysers appeared. Great surface changes.

August 27, 9.15 A.M., also severe.

[1] See *British Association Report*, 1896, pp. 199 and 200.

September 5, 11.30 P.M., also severe.
„ 6, 2.0 A.M. „
„ 19, 11.20 A.M. „ [1]

The above dates and hours, which latter, in all probability, are only approximately correct, become in Greenwich mean time as follows:—

	H.	M.		H.	M.
Aug. 26	11	50	and	22	35
Sept. 5	12	50	„	15	50
„ 19	0	40			

The first of these was recorded at Shide, Edinburgh, Strassburg, Ischia, Potsdam, Nicolaiew, Kew, Paris, and possibly at other places. The remainder were not noted at Shide, because at the hours mentioned the instrument was not working, excepting on the 19th, when there was a heavy tremor storm. The second and third were recorded at Strassburg, and the third and fourth were feebly shown at Edinburgh.

	G.M.T. H.	M.	S.	
Shide Records—				
Commencement	11	23	48	
End of preliminary tremors	11	25	4	
1st max. attained	11	26	12	
2nd „ „	11	27	39	
3rd „ „	11	32	0	
End	12	10	0	
Edinburgh Royal Observatory (Bifilar Pendulum)—				
Commencement	11	10	0	
End	11	30	0	
Kew (Declination Curve)—				
1st small crest	11	27	0	approx.
2nd „ „	11	29	0	„
3rd „ „	11	31	0	„
Paris (*Parc Saint Maur*)—'Magnetic' perturbations observed by M. Moureaux—				
	11	86	0	
	11	42	0	
	11	46	0	

Magnetometers at Greenwich, Falmouth, and Stonyhurst were not disturbed.

	H.	M.	S.
Strassburg (Horizontal pendulum used by Dr. G. Gerland)—			
Commencement	11	22	9
Maximum	11	22	37
Until	12	13	47
End	12	58	37
Rome	11	23	0
Rocca di Papa (15-metre pendulum)	11	26	20
„ „ (7 „ „)	11	36	50
Catania, S.E.–N.W.	11	25	4
„ N.E.–S.W.	11	26	58
Padua	11	30	0
Ischia, E.W.	11	30	54
N. 30° E.–N. 30° W.	11	31	54
N. 30° W.–S. 30° E.	11	31	54

[1] See *Nature*, Oct. 15, 1896, p. 574.

The following table of distances from Hekla, in Iceland, to places where movements were observed, together with the times at which the latter commenced, shows that it is impossible to make any reliable calculations respecting the velocity with which motion was propagated. The causes of the discrepancies are probably to be found in the differences in the form of the instruments employed, and the want of a sufficiently open time scale on many of the record-receiving surfaces :—

	Kms.	H.	M.	S.
Shide	1,831	11	23	48
Strassburg	2,368	11	22	9
Padua	2,775	11	30	0
Rome	3,182	11	23	0
Ischia	3,367	11	30	54
Catania	3,747	11	25	4

Earthquake No. 36 (N.E. Japan, Nambu).

For the phases of this earthquake as recorded at Carisbrooke Castle and at Shide, see 'Report of the British Association,' 1896, pp. 229, 230. The photogram is reproduced in this Report, p. 142.

This shock created considerable destruction in the north-west part of Nippon. It was recorded in Tokio as a slow horizontal movement with a slightly vertical component, but the records from ordinary seismographs were too small for accurate measurement. The time of its commencement in Tokio was, in local time, 5h. 9m. 33s. P.M., or in G.M.T., 20h. 9m. 33s.

When this motion was recorded the disturbance would have advanced 4° on its path towards Europe.

The time taken for three of the various phases of motion to reach Shide and the Isle of Wight, and the velocities of propagation, were as follows :—

	H. M. S.	Velocity on Arc. Kms. per Sec.	Velocity on Chord. Kms. per Sec.
Phase 1. Tremors	13 33	11·11	9·46
„ 3. Heavy motion	47 33	3·15	2·68
„ 5. The maximum	1 4 53	2·3	1 96

The following table is a comparison of the Carisbrooke Castle and Strassburg records :—[1]

	Carisbrooke H. M. S.	Strassburg H. M. S.	Difference M. S.
Commencement of tremors	20 23 6	20 17 50	5 16
„ „ max.	20 57 6	20 29 56	27 10
End	23 16 20	23 38 2	21 42
Duration	2 53 20	3 20 12	26 52
Duration of preliminary tremors	34 0	12 6	21 54

Because earthquake movement dies away gradually and fitfully, it is not at all remarkable that there should be nearly 27 minutes difference in the recorded duration of the disturbance as shown at Carisbrooke and Strassburg. The differences between the two records which are noticeable are in the times at which the preliminary tremors commenced and their duration. Because Carisbrooke is not more than 360 kms. farther from North Japan than Strassburg, it might be expected that the preliminary tremors at the latter place would have been observed about half a minute before they reached the Isle of Wight. A difference exceeding five minutes either indicates that the Carisbrooke instrument is less sensitive

[1] *Nature*, April 15, 1897, p. 558.

than that at Strassburg, or else that between the Strassburg isoseist and the Isle of Wight, motion was propagated at only a little over 1 km. per second, which, it may be noted, is a rate of transmission often observed over short ranges near to an epicentre. An inference to be derived from this is, that for purposes of comparison it is desirable that all stations should be furnished with instruments of equal sensibility.

If we accept the Strassburg record of the arrival of the first tremors as correct, then the average velocity of propagation from Japan to that place exceeded on the arc 18 kms. per second, whereas the average of very many other observations on the same path have yielded apparent velocities of half this quantity.

The origin of this disturbance was along two almost north and south lines in the middle of North Nippon. It may be taken as lying to the north and south of a point in 140° 50′ E. long. and 39° 40′ N. lat.

The times at which the shock was automatically noted at various towns were in local time as follows :—

	H.	M.	S.
Miyako	5	8	55 P.M.
Awomori	5	8	11
Yamagata	5	8	0
Ishimaki	5	8	10
Tokio	5	9	33

The distance between Tokio and Yamagata is about 150 g.m., and Tokio and the origin 240 g.m. Between the first two places the time taken for the vibration to travel was 90 seconds, indicating a velocity of about 10,000 feet per second. Assuming this to be correct, then the time taken from the origin to Tokio would be 2m. 44s., from which it may be concluded that the shock originated at 5h. 7m. 9s., or, in G.M.T., August 30, 20h. 7m. 9s.

The times at which the commencement of this disturbance was noted in Europe were as follows :—

	H.	M.	S
Shide	20	23	6
Strassburg	20	17	50
Ischia	20	20	30
Rocca di Papa (a maximum by a horizontal pendulum)	21	3	50
„ („ „ 7-metre „)	20	55	0
„ („ „ 15 „ „)	20	41	15
Rome	20	21	15
Catania, N.E.–S.W.	20	25	24
„ S.E.–N.W.	20	21	48
Nicolaiew	20	7	30
Time of origin in North Japan	20	7	9

Omitting the observations at Rocca di Papa and Nicolaiew, the following velocities have been determined :—

—	Shide	Strassburg	Ischia	Rome	Catania
Time of transit	15m. 57s.	10m. 41s.	13m. 21s.	14m. 6s.	14m. 39s.
Distance on arc, in kms.	9,290	9,157	9,468	9,564	9,796
Distance on chord, in kms.	8,532	8,147	8,608	8,698	8,864
Velocity on arc, in kms. per sec.	9·7	14 2	11·8	11·2	11·1
Velocity on chord, in kms. per sec.	8·9	13·1	10·7	10·2	10·0

The previous calculation for Strassburg was from the Tokio isoseist, but even the present result seems very high, whilst that for Shide is a little low.

Earthquake No. 47 (September 21, 1896).

—	Distance from Tiflis	Time, G.M.T. H. M. S.
Shide	32° 40′	17 2 2
Fucecchio	—	16 51 50
Rome	23° 18′	16 53 25
Ischia	23° 0′	16 53 58
Padua	24° 0′	16 54 0
Rocca di Papa, E.–W.	—	16 54 0
Catania, N.E.–S.W.	23° 0′	16 54 8
„ S.E.–N.W.	—	16 54 16
Pavia	25° 20′	16 55 30
Nicolaiew	—	16 52 0

The origin may have been near Tiflis.

Earthquake No. 48 (September 23, 1896).

	G.M.T. H.	M.	S.
Shide	11	59	50
Caltagirone	11	50	0
Catania, N.E.–S.W.	11	51	40
„ N.W.–S.E.	11	52	4
Ischia	11	52	8
Rome	11	52	5
Rocca di Papa	11	58	30
Pavia	11	54	0
Nicolaiew	11	52	0

Earthquake No. 49 (September 24, 1896).

	G.M.T. H.	M.	S.
Shide (only partly shown)	10	39	20
Ischia	10	46	33
Rome	10	46	40
Catania, N.E.–S.W.	10	46	50
„ S.E.–N.W.	10	46	47
Nicolaiew	10	49	0

Earthquake No. 56 (October 31, 1896).

	G.M.T. H.	M.	S.
Observations at Shide, Isle of Wight—			
Preliminary tremors commence	17	18	2
„ „ end	17	31	55
„ „ duration		13	53
1. Large waves	17	31	55
2. Maximum	17	53	25
3. Maximum	18	0	35
End of disturbance about	21	0	0
Duration, 3 or 4 hours.			
Nicolaiew, commencement	17	5	30
Ischia, „	17	8	5
Potsdam, shock at	17	21	6

Origin probably Tashkent.

Earthquake No. 67 (November 5, 1896).

	G.M.T. H.	M.	S.
Shide Records:			
Preliminary tremors commence	9	44	58
" " duration		15	46
Maximum	10	0	47
Duration of disturbance about		55	0
Nicolaiew, commencement	9	39	30
Ischia, "	9	54	17

Earthquake No. 73 (*Severn Valley*).

Shide Records, December 16, 1896.

The earthquake which created so much alarm in the Severn Valley at about 5.30 A.M. on December 17, when chimneys were shattered and certain buildings more or less unroofed, was only barely perceptible in the Isle of Wight. The booms of the seismographs at Shide were not slowly tilted from side to side, as is the case when they record earthquakes originating at a great distance, but merely set in a state of elastic vibration, behaving, in fact, like the pointers of seismographs intended to record movements which we feel. The range of these elastic movements, for the most part, were about 1mm., and did not exceed 3 or 4mm. One marked motion commenced at 17h. 30m. 55s., and lasted 5 minutes.

These tremors, which were intermittent and not continuous, as is the case in an ordinary tremor storm, commenced about 11 P.M. on the 16th, and ended at about 11 A.M. next morning. The duration of each group was from 1 to about 6 minutes, and they were separated by intervals of 5 to 60 minutes. Twenty-two of the tremor groups shown by one instrument apparently closely agree in time with 22 maxima shown by a second instrument in another room.

Because there were certainly movements or phenomena observed indicating movements of the ground before and after the chief shock, the approximate times at which a few of the twenty-two groups of tremors were noted are here given.

December 16: at about 11 hrs.; after 14 hrs.; at 15 hrs., two groups; 16 to 18 hrs. an intermittent series, with a maximum about 17h. 30m.; between 18 to 19 hrs., two groups; and the last at about 22 hrs.

Should it be found necessary, the exact time of each of these may be computed from the original photograms.

Details connected with many observations contained in the first two columns will be found in 'Symons's Meteorological Magazine,' January 1897. These observations indicate that during the night of December 16 and 17 persons living in widely separated districts were from time to time disturbed by what they considered to be a tremulous motion of the ground. Because it was night time, in no instance that I am aware of can it be assumed that accurate time observations were made; and, therefore, a few of them have been bracketed together, as possibly referring to the same disturbance.

The Leicester and Hampshire observations, made between 9.30 A.M. and noon, strangely enough, were the result of observing similar phenomena, namely, the twitching of telegraph wires. In Leicester this was seen by a number of persons, the wires vibrating vertically in an unusual and extraordinary manner, there being no wind or other cause to which the movement could be attributed.

Tremors Observed before *the Shock on December* 16, *at about* 17*h*. 32*m*. 1896.

Place	Time	I.W. Seismograph T	Duration	I.W. Seismograph W	Duration
	H. M.				
Rochdale	after 10 0				
Brixton	11 0				
Bangor	13 42	H. M. S.	M. S.	H. M. S.	M. S.
		14 3 52	4 18	14 4 31	2 47
Near Worcester	14 10	14 12 28	2 52	14 11 29	2 47
Maidenhead	14 55	14 36 38	7 10	14 39 11	4 5
Worcester	15 0				
Salop	15 15				
Worcester	15 35				
"	15 50	15 53 57	4 5	15 50 34	5 45
Wolverhampton	16 0				
Droitwich	16 15				
"	16 20	16 25 18	2 44	16 24 3	1 23
Cardiff	16 30				
Hereford	16 50	16 42 2	14 0	16 43 45	max.
Salop	17 0				
Alderley Edge	17 1				
Hereford	17 20	17 10 2	1 24	17 11 29	max.
"	17 30				

Tremors Observed after *the Shock on December* 16, *at* 17*h*. 32*m*. 1896.

Place	Time	I.W. Seismograph T	Duration	I.W. Seismograph W	Duration
	H. M.	H. M. S.	M. S.	H. M. S.	M. S.
Dulwich	17 50	17 54 33	5 45	17 50 5	6 49
Southampton	17 57	18 8 30	13 57	18 5 15	4 5
Leicester	21 30	21 21 3	2 47	21 24 11	5 27
"	23 0	22 42 22	2 52	22 36 27	
	(about)				
Hampshire	after 24 0	23 49 2	22 22		

At the time the tremors were recorded Seismograph T was moving under the influence of convection or other air currents. From time to time, however, it showed maxima of rapid motion, which indicates the existence of an influence superimposed upon the slow swing. The times of the commencement of these maxima are therefore not closely defined. Notwithstanding this want of definition, it is worthy of note that eleven of these records closely agree with the commencement of ten groups of tremor records obtained from Seismograph W in another room, and the times at which persons in various parts of England believed that they had been disturbed by slight earthquakes, or had seen evidences of earth movement.

During the night there were altogether thirteen tremors at which the seismographs moved simultaneously ; but it must be noted that there were

a number of extremely small movements recorded by the two seismographs which did not agree as to their times of occurrence.

Should further comparisons of the records lead to agreements similar to those here indicated, the conclusion will be that England is much more frequently shaken by very small earthquakes than is generally supposed.

Earthquake No. 83 (February 6, 1897).

Shide Records:	G.M.T. H. M. S.
Preliminary tremors commence	19 59 3
2nd max.	20 5 43
3rd ,,	20 9 43
4th ,,	20 15 3
1st large waves commence	20 15 43
,, ,, ,, end	20 22 23
2nd ,, ,, commence	20 23 43
,, ,, ,, end	20 31 43
1st concluding vibrations	20 33 3
2nd ,, ,,	20 35 43
3rd ,, ,,	20 45 3
4th ,, ,,	20 54 23
Duration of preliminary tremors	26 40
,, disturbance, about	1 6 0

Strassburg Records. (Dr. G. GERLAND *with* Dr. EHLERT'S Pendulums.)

—	Begin	End	After Shocks end
	H. M. S.	H. M. S.	H. M. S.
1st Pendulum E. & W.	19 49 50	20 46 19	21 41 39
2nd Pendulum N.W. & S.E.	19 45 25	20 40 20	21 54 0
3rd Pendulum S.W. & N.E.	19 45 25	—	23 30 0

On the third pendulum there were three maxima of tremors.
Duration of preliminary tremors, 38m. 27s.

Potsdam. Dr. ESCHENHAGEN.

From a photographic reproduction of Dr. Eschenhagen's diagrams the following times are obtained :—

	G.M.T. H. M. S.
Commencement of preliminary tremors	19 50 30
Duration of ,, ,,	29 16
Nicolaiew	19 57 0
Ischia	19 55 0

Earthquake of February 19, 1897. *Origin, Japan* (8h. 49m. 0s. G.M.T.).

This earthquake was not recorded at Shide, the clock of the recording apparatus having stopped. It was recorded at other stations as follows:—

	H.	M.	S.	
Edinburgh	9	30	0	(maximum)
Nicolaiew	8	52	0	
Ischia	8	55	30	
Potsdam	9	4	1	

The following are the times (J.M.T.) at which the shock was noted in Japan :—

Miyako.—5h. 49m., strong and sudden, clocks stopped.
Yamagata.—5h. 49m. 10s., strong and sudden, clocks stopped.
Akita.—5h. 49m. 30s., strong and sudden, clock stopped.
Ishinomaki.—5h. 49m. 30s., strong and sudden, clock stopped.
Niigata.—5h. 46m. 36s., strong, clocks stopped.
Fukushima.—5h. 49m. 48s., strong, clocks stopped.
Utsunomiya.—5h. 50m. 0s., strong, houses shaken.
Mayibashi.—5h. 47m. 56s., strong, clocks stopped.
Tokio.—5h. 49m. 37s., strong and slow, clocks stopped.
Mito.—5h. 50m., strong and slow, clocks stopped.
Kofu.—5h. 50m., strong and slow, clocks stopped.
Choshi.—5h. 51m. 24s., strong and long.
Nagoya.—5h. 52m. 36s., strong, clocks stopped.
Nagano.—5h. 50m. 5s., weak and slow.
K'gaya.—5h. 48m., weak and slow.
Awomori.—5h. 50m., weak and sudden, clocks stopped.
Hakodate.—5h. 59m. 48s., weak and sudden, stopped.
Uwajima.—5h. 52m. 45s., weak and slow.
Yokosuka.—5h. 49m. 57s., weak and long.
Yokohama.—5h. 51m. 20s., weak, clocks stopped.
Hamamatsu.—5h. 7m., weak.
Hikone.—5h. 50m. 27s., weak and long.
Gifu.—5h. 57m. 10s., weak.
Kioto.—5h. 51m. 4s., weak, with rumbling.
Fushiki.—5h. 50m. 45s., slight and slow.
Nemuro.—5h. 40m. 45s., slight and long.
Kushiro.—5h. 50m., 50s., slight, with rumbling noises.

The greatest disturbance appears to have taken place at Sendai and in N.E. Nippon, from which it is not unlikely that the origin of the shock was near to that of June 15, 1896 (see Shock No. 1). This being the case, the rate of travel on paths 9,749, 8,760, and 8,241 kms. to Ischia, Potsdam, and Nicolaiew would respectively be 24, 9·7, and 45 kms. per second ! The first and last of these computations we hope to be in a position to correct in some future report.

Examples of earthquakes which have sensibly shaken the whole of North Japan can be found the effects of which do not appear to have reached Europe.

Earth Movements recorded by a Bifilar Pendulum at the Royal Observatory, Edinburgh.

No.	Shide No.	Date		Time, G.M.T.	Remarks.
				H. M.	
1	32	Aug.	25	4 45	Slight tilt to North.
2		,,	,,	5 40	,, ,, South.
3		,,	,,	21 10	Four slight bends in curve, North and South alternately.
4		,,	26	2 10	
5	35	,,	,,	11 15	Gap in curve. No photographic effect produced from 11h. 15m. to 11h. 30m.; broadened and badly defined line 11h. 30m. to 11h. 50m.
		,,	,,	11 50	
6		,,	,,	18 35	Tilt to North.
7		,,	,,	22 50	Gap very similar to the one at 11h. 15m.
		,,	,,	23 20	
8		Sept.	20	1 50	Four bends in curve, South and North alternately.
				3 35	
	45			5 0	
				6 20	
9	47	,,	21	17 5	Trace of diffusion in the curve line. Line slightly bent at several points during the day.
10	48	,,	23	11 57	Line distinctly diffused for 20 minutes.
				12 17	
11	51	Oct.	6	20 10	Bend to North.
				20 30	Normal direction resumed.
				22 46	Bend to South.
12	57	Nov.	2	6 48	Tilt to North.
13		,,	4	22 35	Line very irregular, sinuous.
14	67	,,	5	10 15	
15		,,	26	—	Several very slight irregularities during the day. None well marked.
16	70	Dec.	4	8 16	Small tilt to South.
17	83	Feb.	6	19 33	Large tilt to North, about 2″·5.
		,,	,,	20 25	Line diffused, with well-marked widening to South.
		,,	,,	20 40	
18		,,	7	5 35	Large tilt to North.
19		,,	,,	13 20	,, ,, ,,
20	87	,,	16	8 12	Strong ,, ,,
21		,,	,,	15 17	,, ,, ,,
22		,,	19	9 30	Gap in photographic trace. (At 9h. 30m gap begins abruptly. At 9h. 48m. line is nearly normal for a few minutes. Slight diffusion and widening lasts up to 10h. 2m.)
		,,	,,	9 48	
		,,	,,	10 2	
23	88	,,	,,	12 32	Gap in photographic line. (At 12h. 32m. line shows slight trace of diffusion and widening. 12h. 47m. to 12h. 52m. line is nearly normal, when the gap begins, and ends sharply at 13h. 17m.)
		,,	,,	12 47	
		,,	,,	12 52	
		,,	,,	13 17	
		Mar.	18	2 54	Small tilt to North.

Records received from Professor Kortazzi, Nicolaiew. The Instrument employed was von Rebeur's Horizontal Pendulum. Time, G.M.T.

No.	Corresponding Shide No.	Date	Time: Commencement			Time: Maximum			Time: End			Remarks.
			H.	M.	S.	H.	M.	S.	H.	M.	S.	
		1896										
1	1	June 14	—			22	0	0	—			Record spoiled. Japan.
2	8	" 29	8	47	0	—			9	22	0	Cyprus.
3	8	" 29	9	36	30	—			—			Small. Cyprus.
4	35	Aug. 26	11	22	0	11	37	0	12	22	0	Max. amp. 10mm Also sharp at 11h. 29m. 30s. Iceland.
5	36	" 30	20	7	30	20	33	0	23	7	0	Also sharp at 20h. 17m. 0s. and 21h. 7m. 0s. Japan.
6	39	Sept. 12	17	12	0	17	32	0	18	12	0	Max. 15mm.
7	47	" 21	16	52	0	16	59	0	17	32	0	Max. 35mm. Earthquake in Tiflis.
8	48	" 23	11	52	0	11	57	0	13	52	0	Sharp at 11h. 57m. 30s.
9	49	" 24	10	49	0	11	35	0	12	10	0	Max. 7·5mm. Sharp at 11h. 6m. 0s.
10	56	Oct. 31	17	5	30	17	19	0	19	0	0	Max. 52mm. Sharp at 17h. 10m. 0s. Djarkent and Przewalsk.
11	57	Nov. 2	3	51	0	3	59	0	4	12	0	Max. 4·5mm.
12	67	" 5	9	39	30	9	56	0	11	22	0	Max. 18mm. Sharp at 9h. 44m. 30s. and 9h. 52m. 0s.
		1897										
13	74	Jan. 8	22	24	0	22	52	0	24	38	0	Max. 8mm. Sharp at 22h. 48m. 0s.
14	83	Feb. 6	19	57	0	20	16	0	21	22	0	Max. 30mm. Sharp at 20h. 2m. 0s.
15	85	" 12	14	6	0	14	18	0	15	22	0	Max. 10mm. Sharp at 14h. 16m. 0s.
16	88	" 19	8	52	0	9 10 12	8 16 25	0 0 0	15	2	0	Separated maxima.
17	89	Mar. 1	14	32	0	14	48	0	15	13	0	Max. 4mm.
18	93	" 15	18	31	0	19	22	0	20	12	0	Max. 19mm. Sharp at 19h. 9m. 0s. and 19h. 17m. 0s.

Records received from Dr. Giulio Grablovitz, Director R. Osservatorio Geodinamico di Casamicciola, Ischia.

The movements were recorded on smoked paper by means of two horizontal pendulums.

No.	Corresponding Shide No.	Date	Time, G.M.T. Commencement	Maximum	End	Remarks.
		1896	H. M. S.	H. M. S	H. M. S.	
1	1	June 14	22 49 50	23 33 46 23 36 49	0 30 0	Large.
2	—	" 15	17 38 47	—	—	
3	—	" "	11 23 33	—	—	
4	8	" 29	8 48 20	8 56 3 8 59 25	9 17 0	Moderate.
5	35	Aug. 26	11 30 54	11 39 0 11 41 0	12 0 0	Iceland. Large.
6	—	" "	22 55 30	—	—	" Moderate.
7	36	" 30	20 20 30	21 7 0 21 13 0	22 22 0	
8	—	Sept. 5	12 2 43	—	—	Iceland.
9	—	" 11	20 30 35	—	—	
10	—	" 17	2 53 40	—	—	Calabria.
11	47	" 21	16 53 58	16 59 0	17 20 0	Weak.
12	48	" 23	11 52 8	11 59 0 12 4 0	12 43 0	"
13	—	" 24	10 46 33	—	—	
14	49 or 50	" "	11 54 0	12 7 30	Uncertain	Instrument disturbed by strong wind.
15	—	Oct. 29	23 56 35	—	—	
16	56	" 31	17 8 5	17 31 0 17 34 0	18 32 0	Moderate.
17	67	Nov. 5	9 54 17	10 2 0 10 3 0	10 38 0	"
18	—	" 9	22 32 8	—	—	
		1897				
19	—	Jan. 10	9 8 0	—	—	Gulf of Persia.
20	83	Feb. 6	19 55 0	20 28 0 20 35 0	21 0 0	Moderate.
21	—	" 11	11 53 0	—	—	Calabria.
22	—	" 19	8 55 30	9 45 0	10 20 0	Moderate.
23	88	" "	12 16 0	13 18 0	14 30 0	

Eleven records refer to the same disturbances noted at Shide.

The following observations have been received from Professor Dr. Eschenhagen, Königliches Meteorologisch-Magnetisches Observatorium, Potsdam :—

Records of Magnetographs.

No.	Corresponding Shide No.	Date	Time, G.M.T.	Remarks.
		1896	H. M. S.	
1	35	Aug. 26	11 29 15	Strong on all three magnetographs at 11h. 34m. 45s.
2	—	,, 27	11 2 57	Weak, but strong at 11h. 7m. 45s.
3	36	,, 31	—	Earthquake, but instrument was also artificially disturbed.
4	—	Sept. 5	12 11 45	From Iceland.
5	39	,, 12	—	Earthquake, but instrument was also artificially disturbed.
6	41	,, 14	—	,, ,, ,, ,,
7	47	,, 21	17 6 27	Weak. Strong at 1m. 42s. later. Ends at 17h. 17m. 45s.
8	48	,, 23	12 3 45	Weak for 4m. Also at 12h. 8m. 57s. to 12h. 13m. 27s.
9	56	Oct. 31	17 21 6	Shock, but chief shock at 17h. 27m.
		1897		
10	83	Feb. 6	20 31 57	Duration, 4m. Lloyd's balance.
11	88?	,, 19	9 41 33	,, ,,
—	—	—	9 43 59	,, ,,
—	—	—	9 48 33	,, ,,

Observations with a Conical Pendulum carrying a small Mirror on a Glass Boom 20 cm. in length, and held horizontally by a Quartz Fibre. Period, about 15s. The apparatus is similar to that used for several years in Japan.[1]

No.	Corresponding Shide No.	Date	Approximate Time, G.M.T.	Remarks.
		1897	H. M. S.	
1	—	Jan. 3	11 7 52	Duration, 2h.
2	—	,, 10	9 6 39	,, 1h.
3	—	,, 12	9 6 31	,, 1h.
4	78	,, 16	10 36 29	
5	—	,, 19	14 37 37	
6	83	Feb. 6	20 5 8	,, 2h.
7	84	,, 7	12 5 11	
8	85	,, 12	15 5 23	,, 1h.
9	—	,, 14	3 35 25	
10	—	,, 15	10 5 25	,, 1h.
11	—	,, 19	9 14 31	,, 2h.
12	88	—	12 5 31	,, 2h.
13	—	,, 20	15 50 36	
14	—	,, 23	23 35 50	
15	—	Mar. 2	9 6 10	,, 2h.
16	—	,, 4	12 4 38	,, 1h.
17	—	,, 6	19 5 40	

The lists, it will be observed, are only comparable from January, 1897, after which there are two magnetograph disturbances, corresponding to two movements of the horizontal pendulum. The comparison between these shows considerable differences in time, and indicates the necessity

[1] See *Report of British Association*, 1892.

of obtaining records from similar instruments, each recording on a surface moving with sufficient rapidity to give an open time scale. It is satisfactory to note that twelve of the disturbances were common to North Germany and the Isle of Wight.

The following are more exact determinations of the *commencement* of disturbances, determined from photograms :—

	H. M. S. G.M.T.
No. 4 (Shide 78), Jan. 16 . . .	10 2 6
„ 6 („ 83), Feb. 6 . . .	19 50 30
„ 11 „ 19 . . .	9 4 1
„ 12 („ 88), „ 19 . . .	12 20 9

Observations at Rocca di Papa. Dr. A. CANCANI. (These observations reached Shide too late to be used in computations of velocity, &c.)

No.	Shide No.	Date	Commencement	Maximum	Remarks
		1896	H. M. S.	H. M. S.	
1	1	June 14	22 56 0	23 23 15	Period 18 seconds.
2	8	„ 29	8 48 27	8 52 30	Also at 8h. 59m.
3	35	Aug. 26	11 26 40	11 35 0	End at 11h. 46m.
4	36	„ 30	20 21 0	21 3 0	End at 22h. 16m.; the long waves commenced at 20h. 41m.
5	—	Sept. 5	12 6 0	12 15 0	
6	—	„ 11	20 38 20	20 56 0	End about 22h.
7	47	„ 21	17 0 0 (about)	—	Duration 37m.
8	48	„ 23	11 55 0	12 3 0	End about 12h. 20m.
9	56	Oct. 31	17 0 0	17 31 0	End about 18h.
10	67	Nov. 5	9 59 0	10 1 30	Duration 1h.
11	83	Feb. 6	20 24 0	20 27 19	
12	—	„ 19	8 29 0	9 37 20 9 39 30 9 41 20 9 45 10 9 47 0	
13	88	„ „	11 55 0	13 8 0 13 14 0 13 19 0 13 26 0	

VI. *The Highest Apparent Velocities at which Earth-waves are Propagated.* *By* JOHN MILNE, *F.R.S., F.G.S.*

The following table of the highest apparent velocities with which earthquake motion is propagated over paths of varying length has been drawn up for the purpose of indicating the general character of the information we at present possess bearing upon this subject.

The sources from which information has been derived are various, the more important being as follows :—

'Horizontalpendel-Beobachtungen,' by Dr. E. von Rebeur-Paschwitz ('Beiträge zur Geophysik,' Band II.). These include observations made at Strassburg, Potsdam, Wilhelmshaven, Nicolaiew, Charkof, by the present writer in Japan, by observers in Italy and other places. 'Bollettino della Società Sismologica Italiana,' vols. i. and ii. The catalogues, edited by Professor P. Tacchini, contained in the volumes give prominence to the observations made at Italian stations, whilst observations made in Europe and Japan have not been neglected. 'Transactions of the Seismological

Society,' vols. i.–xx. Seventeen Reports on Seismic Phenomena drawn up by the writer for the British Association, 1881–1896.

With the exception of groups of observations made within a few hundreds of kilometres of an epifocal area, all records which refer to maxima phases of motion, as, for example, those which apparently disturb magnetographs, have been neglected, and therefore, taken as a whole, the velocities given in the following list are based upon the times at which preliminary tremors have commenced to show themselves at various stations.

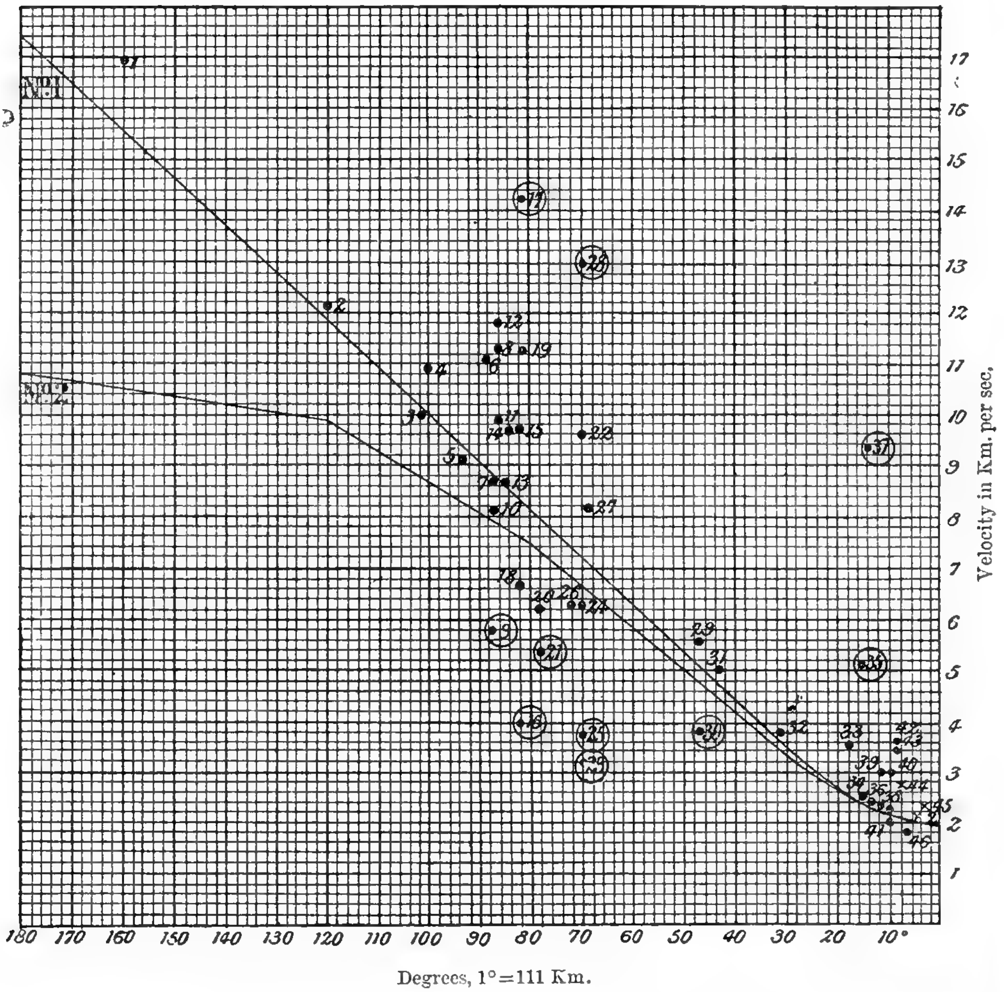
Apparent Velocity of Earthquake Motion along Paths of Varying Length.

Epicentre	Date	Place of Observation	Distance in Degrees	Distance on Arc in Kms.	Velocity in Kms. per Sec. on Arc	—
1. S. A., Santiago . .	Oct. 27, 1894	Tokio	156	17,400	17·0	Mean of observations at three stations in Tokio.
2. " " . .	"	Charkof	119	13,230	12·13	
3. Mexico . . .	Nov. 2, 1894	Nicolaiew	102	11,300	10·0	
4. S. A., Santiago . .	Oct. 27, 1894	Rome	100	11,200	10·85	
5. Merida Venezuela .	Apr. 28, 1894	Charkof	94·8	10,550	9·1	Mean of observations at Charkof and Nicolaiew.
6. Japan, Sakata . .	Oct. 31, 1896	Catania	88·15	9,796	11·1	
7. " N.E. Coast .	June 15, 1895	Ischia	87·8	9,749	8·7	
8. " Sakata . .	Oct. 31, 1896	Rome	86·10	9,564	11·2	
9. " Tokio . .	Oct. 18, 1892	Strassburg	86·6	9,520	5·87	
10. " " . .	Nov. 4, 1892	"	"	"	8·1	
11. " Nemuro . .	Mar. 22, 1893	Rome	86·0	9,500	9·9	
12. " Sakata . .	Oct. 31, 1896	Ischia	85·3	9,469	11·8	
13. " Nemuro . .	Mar. 22, 1894	S. Russia	85·3	9,477	8·7	
14. " N.E. Coast .	June 15, 1895	Padua	84·4	9,320	9·7	
15. " Sakata . .	Oct. 31, 1896	Isle of Wight	83·7	9,290	9·7	
16. California . . .	Apr. 19, 1892	Strassburg	82·7	9,180	3·93	
17. Japan, Sakata . .	Oct. 31, 1896	"	82·5	9,157	14·2	
18. " Tokio . .	Apr. 17, 1889	Wilhelmshaven	81·7	9,070	6·8	
19. " " . .	"	Potsdam	80·6	8,950	11·3	
20. Philippines . .	Mar. 16, 1892	Nicolaiew	78·9	8,758	6·08	
21. " Luzon .	"	"	"	"	5·41	
22. Japan, Tokio . .	May 11, 1892	"	71·2	7,910	9·55	
23. " " . .	Oct. 18, 1892	"	—	—	3·23	
24. " " . .	Nov. 4, 1892	"	—	—	6·28	
25. " " . .	Mar. 23, 1893	"	—	—	3·72	
26. " " . .	Jan. 18, 1895	"	—	—	6·3	
27. " Nemuro . .	Mar. 21, 1894	Mid Italy	70·7	7,857	8·2	
28. " Tokio . .	Oct. 7, 1894	Charkof	70·4	7,814	13·0	
29. Quetta . . .	Dec. 20, 1892	Strassburg	45·7	5,290	5·65	
30. "	Feb. 13, 1893	"	"	"	3·08	
31. Central Asia, Wjernoje	July 11, 1889	Wilhelmshaven, Potsdam	43·3	4,806	5·00	
32. Quetta . . .	Dec. 20, 1892	—	34·6	3,840	3·86	
33. Asia Minor, Amed .	Apr. 16, 1896	Strassburg	18·0	1,990	3·50	
34. Patras	Aug. 25, 1889	Potsdam	15·4	1,732	2·59	
35. Charleston . . .	Aug. 31, 1886	—	15·0	1,678	5·18	
36. Thebes . . .	May 23, 1893	Strassburg	14·8	1,650	2·4	
37. Asia Minor, Amed .	Apr. 16, 1896	Padua	14·0	1,580	9·4	
38. Bucharest . . .	Oct. 14, 1892	Strassburg	13·0	1,450	2·35	
39. Valoria, Epirus .	June 13, 1893	"	12·1	1,350	3·0	
40. " " . . .	"	Nicolaiew	11·4	1,270	3·1	
41. Thebes . . .	May 23, 1893	"	10·3	1,150	2·0	
42. Naples	Jan. 25, 1893	Strassburg	9·0	1,000	3·62	
43. Mount Gargano, Italy	Aug. 10, 1893	"	"	"	3·62	
44. Japan, Nemuro . .	Mar. 22, 1893	Tokio	8·7	965	2·6	Average max. for group of 4 shocks.
45. " Noto . .	Dec. 9, 1891	"	2·4	272	2·3	Average for a group.
46. " Gifu . .	Oct. 28, 1891	"	2·2	241	2·4	Max. for a group of 18 shocks.

A glance at the above table, or the diagrammatic representation of the same (fig. 15), shows that either there have been great differences in the velocities with which movements have been propagated to points equally distant from given origins, which is unlikely, or that there have been larger errors in the determination of the time at which motion commenced at different stations.

Possible causes for these errors are easily found.

FIG. 15.—Velocities of Earth-waves round or through the Earth.



1. Different instruments; some being horizontal pendulums recording photographically, others being pendulums varying in length and in the frictional resistance of pointers recording on smoked surfaces, may have unequal degrees of sensibility.

2. Similar instruments may be differently adjusted.

3. When a record is received on a surface moving at a rate of about 20mm. per hour, the error in determining the time at which a disturbance commenced may be 1 minute.

4. A local shock may be mistaken for one arriving from a distance.

Examination of Cases where the Velocity has been Abnormally High.

Shock No. 1.—This was recorded at three stations in Japan by horizontal pendulums recording on photographic surfaces. From the fact that ordinary seismographs did not record an earthquake on that day, and because each photogram began with gentle tremors, it is safe to assume that they represented an earthquake originating at a great distance. Unfortunately, the note-books containing the clock corrections were burned, but taking the time determinations direct from the photograms, they lead to the conclusion that motion was propagated to Japan from a place almost at its antipodes at a rate varying between 16 and 19 kms. per second.

The greatest merit in this record is that it falls in line with what we should expect from records taken over shorter ranges.

Shock 17.—Like other Strassburg records, this was obtained on paper moving at a rate of about 1 mm. in three minutes. Independently of this, however, we see that for the same shock at four other observatories velocities of 9·7, 11·1, 11·2, and 11·8 kms. per second have been calculated (Nos. 15, 6, 8, and 12), and it is therefore highly probable that the determination for Strassburg of 14·2 kms. is too high.

Shock 28.—We have here another case of a record from a surface moving at a rate of 1 mm. in about three minutes, whilst the epicentre may have been distant from Tokio.

Shock 37.—Because a delicate seismograph at Catania was disturbed 2 minutes 40 seconds *before* the one at Padua suggests the idea that these Italian records possibly refer to a local disturbance, and not to the one in Asia Minor. This point has been discussed by Professor M. G. Agamennone (see 'Bollet. A. Soc. Sis. Italiana,' vol. ii., No. 8).

Shock 35.—This estimate is based upon a most careful and elaborate analysis of records, none of which, however, were obtained from the automatic indications of seismographs.

Abnormally Low Velocities.

Shocks 9 *and* 23.—We have here two observations for the same shock, and we find that the photograms obtained at Strassburg and Nicolaiew were 'schwach und wenig scharf,' and for the former there was an 'unbestimmter anfang,' from which it may be concluded that the commencement of movement at these places was not determined.

Shock 21.—From the Nicolaiew record it appears that the commencement of this disturbance is thus noted : '5·02 h. (?) Anfang der Storung.' The uncertainty here expressed possibly explains the low velocity recorded.

Shock 16.—Here again there appears to have been difficulty in determining the commencement of movement, owing to the undefined character of the photogram.

Shock 25.—This was observed not only at Nicolaiew, but also at Strassburg, the velocities being 3·72 and 4·2 kms. per second respectively. Although von Rebeur in his 'Horizontalpendel-Beobachtungen,' p. 492, tells us that these velocities are based upon the observation of the time at which the first weak movement is visible, from a table on p. 443 they appear to have been determined from the observation of the instant at which there was a sudden increase in motion, and are used with other

observations to determine the *mean* velocity of propagation, which is that of the greatest movements.

Shock 3.—Movement in Europe was extremely small, and no record was obtained at Nicolaiew. Possibly the smallness of the diagram, which began 'little by little,' may have rendered it difficult to make accurate measurements on the time scale.

The general result of the examination of data which have led to the determination of velocities which appear to be either too high or too low, is to find that such data are either imperfect or capable of another interpretation.

The doubtful cases are placed in circles, and to these, based upon a long experience in observing earthquake velocities over ranges up to about 1,000 kms., I should be inclined to add Nos. 33, 39, 40, 43, and 42.

If, therefore, we exclude the computations the accuracy of which is doubtful, the general results towards which the continuation of the observations on the propagation of earth-waves over ranges of varying length point is approximately indicated in the following table :—

Distance from Origin		Apparent Velocity in Kms. per Sec.	
In Degrees	In Kms.	On Arc	On Chord
10	2,200	2 to 3	2 to 3
50	5,500	5	5
80	8,800	8	7·5
100	11,100	10	8·8
120	13,200	12 ?	10 ?
160	17,700	16 ?	10·5 ?

VII. *Diurnal Waves.* *By* JOHN MILNE, *F.R.S.*, *F.G.S.*

Observations made on the Tennis Ground at Shide Hill House. Installation V.

On September 5, 1896, the horizontal pendulum which had been in use at Carisbrooke Castle was brought to Shide, where it was installed on a slate slab resting on an upended earthenware drain-pipe, sunk some inches in the ground, covered by a jointer's tent standing in the middle of a tennis ground. The chief object of this installation was to study the diurnal wave, as shown by the movements of a pendulum so placed that for ten or twenty yards, at least, on all sides of it the surface conditions were fairly similar. The tennis ground is in the middle of a small paddock which slopes towards the west. On the eastern side, at a distance of forty yards, is the building in which instrument T was installed, beyond which the ground quickly rises to Pan Down. The sun, rising on this side, reached the tent over the top of some high trees at about 9 A.M., throwing the shadow of the tent towards the N.W. At about 4 P.M. this shadow, after travelling through N. to the N.E. was lost, as the sun sank behind Mount Joy on the west.

The bromide film was run at a rate of about $3\frac{1}{2}$ inches in twenty-four hours, which was sufficiently rapid to give an easily measurable diagram of the daily movement of the pendulum, the boom of which pointed from its pedestal towards the south.

On September 13 a heavy tarpaulin (30 × 30 ft.) was spread over the grass, immediately up to the tent on its west side. On October 13 this

was moved to the east side, the object being to see whether such a covering had any effect on the character of the diurnal wave.

The Observations (1896).

1st week (*Sept.* 8–14).—From the 8th to the 14th daily waves were marked, but there was such a marked steady displacement towards the valley on the west that adjustments were required almost daily.

On the 8th and 14th it was fairly fine, but on all the other days there was much rain and the weather was dull. The westerly motion, or downward tilting towards the saturated valley, was also marked in the records of T.

2nd week (*Sept.* 14–21).—Because the westerly motion had been so great the sensibility of the instrument was reduced, with the result that the daily wave was hardly visible. There was still, however, a westerly tendency. The weather was dull or fine, but there was no heavy rain.

3rd week (*Sept.* 21–27) :—

Sept. 21. 15–24 hours slight tremors. Fine. S. wind.
„ 22. 18–20 hours slight tremors. Fine. Strong S.W. wind.
„ 23. Steady. Fine. Strong S.W. wind.
„ 24. 12–19 hours slight tremors. Fine. W. wind. Rain at night.
„ 25. Steady. Strong wind, rain.
„ 26. Steady. Rain, but calm.
„ 27. Steady. Stormy. S.W. wind.

On the 21st, 22nd, 23rd, and 24th there were slight daily waves, but after adjustment on the 25th the movement was barely visible.

It may be inferred that with cloudy weather the daily wave has been small. The shock shown by T on the 21st is not shown.

4th week (*Sept.* 28–*Oct.* 2) :—

Sept. 28. East motion completed 4 P.M. Fine. W. wind.
„ 29. East motion completed 4.45 P.M. Rain. S. wind.
„ 30. East motion completed 2·30 to 3.30 P.M. Fine. N. wind.
Oct. 1. East motion completed 3 30 P.M. Fine. W. wind.

For six hours before the above times the motion was easterly, and for six hours after it was westerly. In no instance were the waves large.

Two slight disturbances were noted, but these do not agree in time with displacements observed on T.

5th week (*Oct.* 2–9) :—

Oct. 2. East motion completed 5 P.M. West motion completed at 10.50 P.M.

On all other days no movement. This was discovered as being due to a spider, which was caught on Oct. 10.

6th week (*Oct.* 9–15) :—

Oct. 9. East motion completed 3.15 P.M., and west at 9 P.M. Amp .9mm. Fine. W. wind.
„ 10. East motion completed 4 P.M. Amp. 3mm. Fine. S. breeze.
„ 11. No record. Dull. N. wind.
„ 12. East motion completed 6 P.M., and west at 18hrs. Amp. 3mm. N. breeze. Dull.
„ 13. Record bad. A large tarpaulin placed on ground on west side of tent. Fine. N. wind.
„ 14. East motion completed about noon. Wave small. Fine. N.E. wind.
„ 15. East motion completed 3 P.M., and west at 6.50 P.M. Amp. 6mm. Little rain. Dull. S. wind.

We have here a case (on Oct. 15), where there has been a fairly large wave on a dull day, and a small one (Oct. 10) on a fine day.

Very small tremors were seen on the following days :—

Oct. 9. 5 to 9 hours.
„ 14. 7 to 14 „
„ 15. 4 to 7 „ and again 11 to 22 hours.

Three displacements were recorded which do not agree in time to those noted by T.

7th week (Oct. 16–22) :—

Oct. 16. Very slight wave. Dull. Strong N. wind.
„ 17. East motion completed 2h., and west at 6 P.M. Amp. 6mm. Fine. N. wind.
„ 18. East motion completed 3h., and west at 10 P.M. Amp. 14mm. Fine. N.W. wind.
„ 19 to 20. Practically straight; possibly held fast.

The diurnal waves were marked on fine days.

Slight tremors were only observed on the 16th, 0 to 14 hours. There was one strong deflection on the 16th, which is not shown on T.

8th week (Oct. 23–30) :—

Oct. 23. East motion completed 2h. 30m., and west about 8 P.M. Amp. 11mm. Fine. N. wind.
„ 24. East motion completed 1h., and west about 12 P.M. Flat. Rain. S.W. wind.
„ 25. East motion completed 3h. 30m. Fine. N. wind.
„ 26. No record.
„ 27. East motion completed 2h. 30m., and west about 8 P.M. Amp. 14mm. Fine. W. wind.
„ 28. East motion completed 4h., and west about 9 P.M. Amp. 10mm. Fine. W. wind.
„ 29. East motion completed 3h., and west about 7 P.M. Amp. 10mm. Fog. Calm.

It is difficult to say when the west motion is completed. The sharp motion eastwards is from about 8 A.M. to 3 P.M., and westwards 3 P.M. to 8 P.M. Decided waves have been with fine weather, when cloudy and wet, waves have been absent.

Slight tremors were observed as follows :—

Oct. 23. 3 to 7 hours and 18 to 21 hours.
„ 24. 11 to 21 „
„ 25. 8 to 15 „
„ 27. 3 to 8 „
„ 28. 4 to 8 „
„ 29. 3 to 8 „

Tremors, therefore, occurred at night, and whilst there was a rapid westerly displacement. Moderately marked displacements took place on the 23rd to 24th, which are not shown by T.

9th week (Oct. 30–Nov. 6.) :—

Oct. 30. No record. Moved tarpaulin to the east side of tent.
„ 31. East motion 10 A.M. to 2.30 P.M., west motion 2.30 P.M. to 6.30 P.M. Amp. 8 mm. Fine. N. wind.
Nov. 1. East motion 3 A.M. to 3.0 P.M., west motion 3 to 8 P.M. Wave small. Dull. N.E. wind.
2. No record.

Nov. 3. East motion 5 A.M. to 2.30 P.M., west motion 2.30 P.M. to 6 P.M. Amp. 4 mm. Dull. N. wind.
„ 4. East motion 10 A.M. to 3 P.M., west motion 3 P.M. to 7.30 P.M. Amp. 8 mm. Fine. N. wind.
„ 5. East motion 8.30 A.M. to 3 P.M., west motion 3 P.M. to midnight. Amp. 10 mm. Fine. E. wind.

The greatest movements have been on the fine days.

Tremors were observed on October 30, 3 to 17 hours, of 2 mm. range, and slight tremors on October 31 and November 4.

Three displacements were noted which do not agree with the records of T, but the earthquakes Nos. 55 and 59 shown by T were well recorded.

10*th week* (*Nov.* 6–13.) :—

Nov. 6. East motion from before noon to 2.30 P.M., west motion 2.30 to 8 P.M. Amp. 7 mm. Fine. N. wind.
„ 7. East motion 6.30 A.M. to 3.0 P.M., west motion 3 to 6 P.M. Amp. 1 mm. Fog, frost.
„ 8. No wave, but westerly displacement midnight to 7 A.M. Rain. N. wind.
„ 9. East motion from before noon to 2.45 P.M., west motion 2.45 to 8 P.M. Amp. 7 mm. Fine. N. wind.
„ 10. East motion 9 A.M. to 3.30 P.M., west motion 3.30 to 7 P.M. Amp. 6 mm. Fine. Calm.
„ 11. East motion from before noon to 2 P.M., west motion 2 to 6 P.M. Amp. 1 mm. Dull. W. wind.
„ 12. East motion 9 A.M. to 3 P.M., west motion 3 to 6 P.M. Amp. 8 mm. Dull. S. wind. Afterwards fine.

The diurnal wave is evidently pronounced on fine days, and small or absent when it has been rainy, cloudy, or dull.

Tremors were noted as follows :—

Nov. 6.	4 to 12 hours.	Slight.	
„ 7.	7 to 22 „	Maxima of 2 mm. at 19 hours.	
„ 9.	4 to 12 „	„	1 mm. at 6 hours.
„ 10.	6 to 11 „	„	1 „
„ 11.	18 to 20 „	„	5 „
„ 12.	4 to 13 „	„	1 „

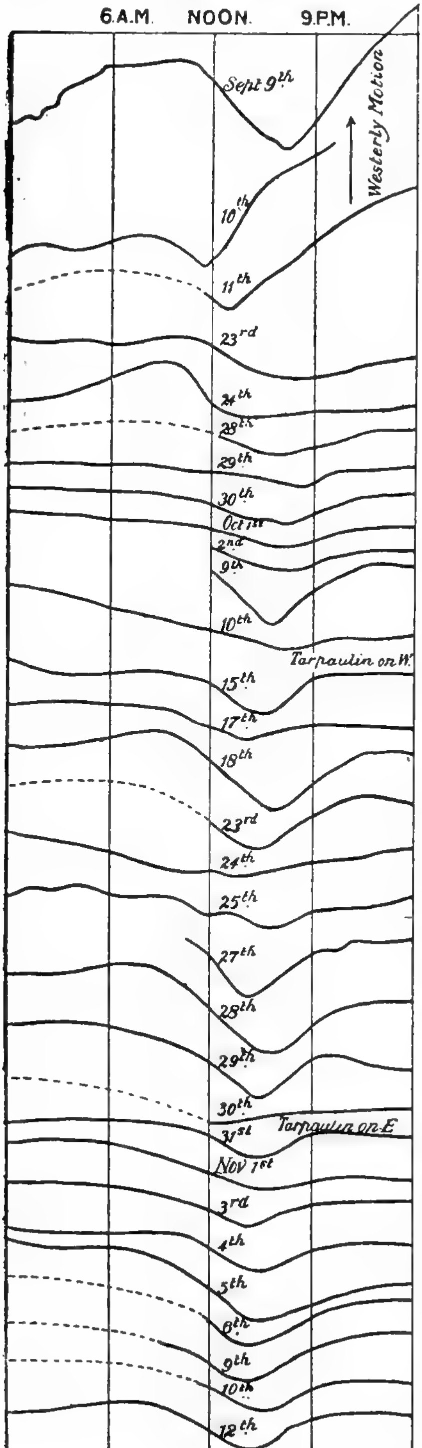
Six small displacements were noted, which do not agree with the records of T.

The Diurnal Wave.

Figure 16 shows half-size tracings of daily waves taken from the original photograms. Angular values for these waves may be approximately obtained by assuming that 1 mm. deflection corresponds to a change in inclination of 0·5 sec. of arc. Should accurate measurements of these quantities be required, they can be obtained from my note-books.

Days on which the diurnal wave was very small have been omitted. The curves which are given clearly show that the daily deflection is variable in amount; but whether the ground around the tent was open, or covered by a tarpaulin on the west side or on the east side, the times at which the pendulum commenced, completed, and ended its sharper movements are practically the same. If we commence in the morning, the direction of movement of the pendulum from a north-south line, or its normal position, was such that it tended to approach a position that would place its boom in a line with the sun and the shadow of the tent. That is to say, it swung towards the east, but it continued this motion

FIG. 16.—Diurnal Waves at Shide, 1896.



until the sun had passed the meridian, or until 2 or 3 P.M. Then it returned, following the sun until 7 or 9 P.M.

The text accompanying these diagrams shows that the movements are practically confined to fine days, from which it may be concluded that the effect is connected with solar radiation.

In previous reports I have suggested that it might be produced by the difference in load removed by evaporation on two sides of an installation, such loads from a surface of grass being represented by the removal of 4 or 5 lb. per square yard per day.

The experiment with the tarpaulin-cover placed first on one side of the tent and then on the other, which failed to produce any marked effect on the character of the diurnal motion, indicates not only that this is practically uninfluenced by differential evaporation effects, but also by the heat received by the ground on two sides of an installation, these effects being local. We therefore have to look to the instrument, the pier on which it stands, or external effects on a widespread area. The fact that the diurnal wave is marked on a brick pier rising from a solid foundation in the middle of a brick building shaded by trees,[1] and also in cellars, in both of which places the changes in temperature have been small, indicates that the movements are not to be accounted for by warpings on the pier or portions of the instrument.

The fact that strong and steady westerly deflections corresponding to an increase on the slope of the hill on which T and V stood accompany wet weather, and that reverse movements follow fine weather, indicates that a load in the valley apparently causes this to sink, whilst during the removal of such a load it apparently rises. It seems natural to conclude that the diurnal waves are movements with a similar origin. On hot days the valley loses moisture, and therefore it rises,

[1] *British Association Report*, 1896, p. 213.

and the pendulum travels eastwards, whilst at night moisture is accumulated, and it sinks.[1]

VIII. *The Perry Tromometer.* *By* JOHN MILNE, *F.R.S., F.G.S.*

A Perry Tromometer, similar to that described in the Report of this Committee for 1896, with photographic recording apparatus, has been constructed, and for some days installed at Shide. Its sensitiveness to elastic tremors was such that it recorded trains moving at a distance of over half a mile, carriages at a distance of a quarter of a mile, and all vehicles passing along a road near to the building in which it was placed. For these reasons it was dismantled, but it may be again used when a site free from the above-mentioned artificial disturbances, to which may be added the sound-waves from heavy guns fired at a distance of five or six miles, can be found.

In conclusion to the preceding sections of the Report the fact that the records of earthquakes and other movements have been continuous has been in consequence of the great interest taken in the observations by my assistant, Shinobu Hirota, who not only understands the working of the instruments in all their details, but has from time to time shown considerable ingenuity in devising and constructing new pieces of apparatus.

IX. *Sub-oceanic Changes.* *By* JOHN MILNE, *F.R.S., F.G.S.*

The object of the following notes, which are an epitome of a paper to be communicated to the Royal Geographical Society of London, is to show that beneath seas and oceans there are a certain class of geological changes in operation which are more frequent, and often more intense, than corresponding changes on land.

The sites of these changes are to be found below low-water mark at comparatively shallow depths on submerged plateaus surrounding continents and islands, and on the face, and especially near to the base of the steeper slopes of continental domes, and around submarine banks at depths which may even reach 4,000 fathoms. On the level floor of oceans, where sediments accumulate with immeasurable slowness, and where for years and years ocean cables lie undisturbed, geological changes are, so far as a lifetime is concerned, not recognisable.

The submarine operations to which it is particularly desired to draw attention are those which are seismic and volcanic, the former at least often being accompanied by the displacement as a landslide of such enormous volumes of material that the whole surface of an ocean may be agitated. Evidences that such displacements have had a reality is to be found in the conditions under which cables have been buried, and in the marked change in soundings near to spots where seismic efforts have been exerted.

Other causes leading to displacement of materials on the face and near to the base of submerged slopes are overloading by sedimentation, erosion, the escape of water from submarine springs, and the effects of currents.

The various sub-oceanic phenomena to which it is particularly desired to call attention will be treated in the following order:—

1. *Bradyseismic action.*—Because earthquakes originating beneath

[1] *British Association Report*, 1895, pp. 133–139.

the sea are more numerous and more intense than those originating on land, the inference is that bradyseismic activity and phenomena which accompany earthquakes, like landslides, are also more pronounced beneath the sea than they are on land.

Bradyseismical movements include movements of upheaval or depression, by which rocks are bent, folded, faulted, or displaced, by thrust, together with those which are the result of overloading, and may be exhibited as basal crush. One set of movements involve the idea of elastic and seismic strain, whilst the others a gravitational effect.

2. *Sedimentation and erosion.*—Submarine landslides which in part are due to earthquakes.

The effects of overloading, submarine springs and currents.

3. *Changes evidenced by cable interruptions and soundings.*

4. *Conclusions.*

1. *Bradyseismic Action.*

Earthquakes the Origin of which are Submarine.—The earthquakes which have a submarine origin may be divided into three groups:—

1. Those which have been felt and recorded on land, and which, therefore, may be assumed, in the generality of cases, to have originated on a coast-line or within a few hundred miles off in the ocean.

2. Those which have been recorded on shipboard out at sea, either as tremors or as severe movements. Many of these disturbances are probably volcanic.

3. Those which have not been felt on land, but have been distinctly recorded there. In this group we find many of the earthquakes which shake the world.

As illustrative of the frequency of the first group, I will quote from observations made in Japan.[1] Between 1881 and 1883 in North Japan the writer found that, out of 419 shocks, no less than 218 of them had originated beneath the ocean. There had been 137 which had originated on or near the seaboard, and therefore some of these had been of sub-oceanic origin, whilst only 64 had originated inland. A large number of these earthquakes came from the deep water off the mouth of the Tonegawa, the largest river in Japan, which, as it approaches the sea, crosses the alluvial plain of Musashi.

Between 1885 and 1892 no less than 8,331 earthquakes were recorded in Japan—that is, on the average during this period of eight years there were about one thousand shocks per year.[2] A glance at the map showing the distribution of origins of these disturbances shows that nearly all of them have originated along the eastern seaboard, and have been frequent near the alluvial plains. Between January 1885 and December 1888, when seismic activity was in a normal state—that is to say, when there were no long series of after-shocks—2,018 earthquakes were recorded, of which at least 1,034, or 50 per cent., originated beneath the sea. In Japan, therefore, along a coast-line of 1,140 miles, there has recently been at least about 250 submarine shocks per year. In some years there have been 500.

From a seismic map of the world, I should estimate that round the

[1] 'On 387 Earthquakes observed during Two Years in North Japan,' by John Milne, *Trans. Seis. Soc.*, vol. vii. pt. ii.

[2] *Trans. Seis. Soc.*, vol. xx.

Pacific there are at least ten sub-littoral districts where earthquake frequency may be about half that of Japan. If this is accepted as probable, the sub-littoral seismic activity of the Pacific is represented by 2,500 shocks per year, some of which have been accompanied by submarine landslips and consequent changes in the configuration of the ocean bed. When these latter are great, it is assumed that ocean-waves are created. If we consider the seismic activity round the coasts of the other oceans and seas which cover our globe as being, when taken together, equal to that of the Pacific, then for the world, out of a possible 10,000 shocks per year, 5,000 of them have their origin on the sub-oceanic continental slopes.

To get information about the second group, or earthquakes which have originated far from land, we have to turn to the voluminous catalogues of Perrey, Mallet, Kluge, di Ballore, Fuchs, and other statisticians. Such extracts have been made by Dr. Emil Rudolph in his papers, 'Ueber Submarine Erdbeben und Eruptionen,'[1] who gives us an account of 333 sub-oceanic earthquakes and eruptions. Because the greater number of these shocks are of volcanic origin, they will be more specifically referred to in the next section. The distribution of these is various, but here and there they herd together, indicating localities where changes are comparatively rapid. One favourite locality for submarine disturbances is in the Equatorial Atlantic, about 20° W. long., and again at 30° W. long., near to St. Paul's. For each of these regions Dr. Rudolph gives about thirty-seven shocks, in depths of water exceeding 1,000 and 2,000 fathoms.

The chief source of information for our last group is, however, derived from the records of horizontal pendulums. Taking a list of them published in the 'Transactions of the Seismological Society,' vol. xx., by the late Dr. E. von Rebeur-Paschwitz, out of 301 records obtained in twenty-seven months, there are only 25 which can with certainty be traced to their origin. Out of the 176 which remain, 105 were almost simultaneously recorded at places so widely separated as Potsdam, Wilhelmshaven, Strassburg, Nicolaiew, and Tokio, and therefore cannot be disposed of as being due to some accidental disturbance of an instrument or to small shocks of local origin. Each of them was a disturbance affecting a very large area, and indicates an initial impulse of great magnitude. What is true for the observations in Europe has also been true for my own observations in Japan, and also in the Isle of Wight, the only difference being that in Europe the stations were from 300 to 600 miles apart, whilst in Japan and the Isle of Wight the stations were usually near to each other, and never more than 30 miles apart. In some instances, however, earthquakes of unknown origins were recorded in Japan and Europe, and it is fair to assume that in these instances the whole world had been shaken.

One disturbance noted by the author in Japan on June 3, 1893, had a duration of five and a half hours. It was also recorded in Birmingham, Strassburg, and Nicolaiew, at which latter place the duration of motion extended over eleven hours. Amongst unfelt earthquakes, both for magnitude and duration, it exceeded all that have yet been recorded.

Because the character of the unfelt movements, the origin of which cannot be traced, is identical with the character of those which have been

[1] *Beiträge zur Geophysik*, Band I. and II.

traced to earthquakes originating at great distances, it is, for the present at least, assumed that the cause of the former is similar to the cause of the latter. If this is the case, the only place towards which we can turn to find the origin of the former appears to be beneath our oceans, and when they are of a magnitude approaching that of June 3 their origins must have been very far from land, otherwise a sensible shaking would have been observed upon the nearest shores.

If we take the three classes of records to which we have referred in conjunction, the conclusion to which they point is not simply that the submarine evidences of seismicity are more numerous than those on land, but also that they are very much more intense.

The Character of Submarine Seismic Districts.—If we compare together the characters of the districts where earthquakes of submarine origin are frequent with those where they are practically unknown, the differences are striking. In the former the land, as shown on the seaboard, usually consists of strata which are geologically new ; it exhibits evidences of recent elevation, some of which can be traced to historical times, whilst its average slope from the mountains in the interior down beneath the ocean is, over a considerable distance, relatively very steep.[1] The unit of distance over which such slopes have been measured is taken at 2°, or 120 geographical miles. The following are a few examples of such slopes :—

West Coast, South America, near Aconcagua	1 in 20·2	Seismic districts.
The Kurils from Urap	1 in 22·1	
Japan, west coast of Nippon	1 in 30·4	
Sandwich Islands northwards	1 in 23·5	
Australia generally	1 in 91	Non-seismic districts.
Scotland from Ben Nevis	1 in 158	
South Norway	1 in 73	
South America, eastwards	1 in 943	

The conclusion derived from this is, that if we find slopes of considerable length extending downwards beneath the ocean steeper than 1 in 35, at such places submarine earthquakes, with their accompanying landslips, may be expected. On the summit of these slopes, whether they terminate in a plateau or as a range of mountains, volcanic action is frequent, whilst the earthquakes originate on the lower portions of the face and base of these declivities.

The Cause of Seismic Strain, Deformation, Thrust, and Crush.—We assume that the contours referred to in the last section are mainly the result of rock-movement, and that seismic strain, due to a tendency to further adjustment, is greatest where earthquake origins are most frequent. The home of the volcano is evidently the place where the rocks have been most deformed, whilst that of the earthquake is at the base of steep sub-oceanic slopes where most deformation is in progress. The nature of the forces in operation producing this deformation is twofold. First, there is the horizontal thrust, so strongly emphasised by Lapworth, which may or may not tend to increase the height of the mountain ranges bounding its line of action ; and, secondly, a factor dependent on gravity, which, acting on the side of subaërial and marine denudations, tends to lower them. Earthquakes are for the most part spasmodic accelerations in processes with these characters.

[1] See 'Note upon the Geographical Distribution of Volcanoes,' by J. Milne, *Geol. Mag.*, April 1880. Also address to the Geological Section of the British Association, in 1892, by Professor C. Lapworth, LL.D., F.R.S.

The distortions observed in fossils and pebbles, the difference in thickness of contorted strata, and the 'creep' in coal-mines, all indicate that great pressures may set up movements in stratified materials corresponding to a flow. Mr. William Barlow, in a paper on the 'Horizontal Movements in Rocks,'[1] as evidence of this, calls attention to the contortions and foldings observed in glacial drift produced by a load above, the dip seen on the face of the Grand Cañon of Colorado, and the slight elevation observed in the area surrounded by cliffs known as the 'San Rafael Swell.' These and other appearances may be regarded as instances of 'creep' upon a large scale, when materials have been squeezed out from beneath superincumbent strata.

In studying bradyseismical movement we usually take cognisance of that which is most apparent. This is the vertical component of a displacement, whilst the horizontal movement may be entirely overlooked. The geotectonic structure of many countries, however, shows us that displacements by horizontal thrust have taken place on an enormous scale, and it is not unlikely that these forces, accelerated by the effects of crush, are yet in operation round the basal contours of continental areas. Sub-oceanic earthquakes are therefore announcements that sub-oceanic bradyseismic action is in progress, and because these disturbances are more numerous round the submerged frontiers of continental domes and in mid-ocean than they are on land, it may be concluded that the distortions and displacements due to bending, thrust, and crush are greater beneath the sea than they are upon continents and islands.

Earthquakes and Landslides.—In addition to these bradyseismical effects, which only produce appreciable changes in sub-oceanic contour after the lapse of long intervals of time, there are the effects which accompany the actual shaking, which we may assume are not far different from those effects which we see produced by earthquakes originating on land. Many earthquakes which we feel, although they may create alarm and shatter chimneys, do not produce any effect upon rocks and cliffs. This, however, does not preclude the idea that shakings of equal intensity would not produce effects upon submarine slopes, where, as compared with similar slopes on land, critical conditions may more nearly approach in character to the mechanism of the hair trigger. Severe earthquakes on land are almost always accompanied by great landslides, and mountains which may for ages have been green with forest growth by the sliding away of materials on their sides suddenly present the appearance of having been whitewashed. The probable effect of similar shakings originating beneath the ocean in the vicinity of steep slopes needs no explanation.

Another effect which sometimes accompanies these disturbances, and which may have been their cause, is the creation of a fault 50 or 150 miles in length, by which the country on one side of this, relatively to that on the other, has been suddenly raised or lowered 20 to 30 feet. Earthquakes of this nature, if of submarine origin, would naturally produce similar effects over large areas, and, if the magnitude of the displaced materials, whether by landslides or faulting, were large, as compared with the depth of the superincumbent waters, would also give rise to sea-waves.

One of the most recent examples of effects of this description was that which occurred on June 15, 1896, off the north-east coast of Japan. On

[1] *Quart. Journ. Geol. Soc.*, November 1888.

the evening of that day a submarine earthquake occurred in this locality which was recorded in the Isle of Wight; and, from the magnitude of the diagrams, it may be assumed that the world was shaken from pole to pole. Following this shaking, great sea-waves spread over the North Pacific Ocean. The explanation of these phenomena is that the earthquake was produced by fracture of the rocks, not at a point, but over a considerable length, which movement, being accompanied by the displacement of huge masses of material, gave rise to the sea-waves. The sub-oceanic contour of this locality, where the depth of the water increases at the rate of 1,000 fathoms in 25 miles until the 4,000-fathom line of the Tuscarora Deep is reached, lends itself to this supposition. The only difficulty we experience is to estimate the volume of the material which must have been more or less suddenly displaced at these great depths to have produced so great a disturbance on the surface of the ocean. It is not likely that it was less than that of the greatest landslide of which we have historical record as having occurred upon the surface of the earth.

The data we have for calculating the position of the origin of these great disturbances are numerous and exact. Our knowledge of the dissipation of earthquake energy, as represented by its destructivity as it radiates, indicates that an earthquake which dislodged sufficient material to disturb the whole of the North Pacific Ocean must, at the very least, have originated 100 miles away from Miyako, on the north-east coast of Nippon, at which places a few houses were shattered.

The calculations to be found on p. 157, strangely enough, bring us exactly to the base of the western boundary of the Tuscarora Deep, above which there are 4,000 fathoms of water. This is a place from which many earthquakes have originated, affording evidences, particularly in this instance, of sudden sub-oceanic changes along the basal frontier of a continent the magnitude of which it is difficult to estimate.

Submarine Volcanic Action.—If highly heated rocks saturated with water were the only condition necessary for a display of volcanic action, such activities might be as marked in ocean basins as round their margins. The geological distribution of volcanoes, however, shows that before a volcanic magma can expend and find exit on the surface, the pressure due to superincumbent strata must be relieved, which is apparently obtained when they are sufficiently crumpled upwards to form mountain ridges. If, therefore, we seek for volcanic action beneath the sea, we may expect to find the same along submarine ridges, and if we discover the same, as we do along the central ridge of the Atlantic, the conclusion is that along such a ridge an upward bradyseismical movement is in progress, and not far from the region of eruptions there should be a region of earthquakes.

In certain instances, apparently, as is the case with the Aleutians and the Kurils, so many eruptions have taken place along a submarine ridge that a continuous and almost connected chain of islands has been formed. On the flanks of the most southern of the latter group recent marine strata have been raised, which, taken in conjunction with the fact that hardly a year passes without some new eruption being noted, whilst submarine shocks of earthquakes are frequent, indicates that Japan may in time become connected with Kamschatka.

Any attempt to enumerate the various submarine ridges of volcanic activity at present evidenced by these outcrops would be beyond the scope of the present paper. One curious form of evidence, indicating the existence of volcanic activity entirely hidden in ocean depths, is referred to by

Mr. W. G. Forster, in his paper on 'Earthquake Origin,'[1] from which we learn that cables have, after their interruptions, been recovered from which the gutta-percha had been melted—probably by water at a high temperature. The cables referred to are near the Lipari Islands and between Java and Australia.

Some idea of the frequency of earthquakes and volcanic shocks originating in the ocean may be obtained from a paper by Dr. Emil Rudolph.[2] From his descriptions, which are derived from the catalogues of Perrey, Mallet, the archives of the London Meteorological Office, &c., the following table has been drawn up :—

North Atlantic, 1724–1886	28	disturbances.
Azores, 1843–1884	20	,,
Cape Verde Islands, 1854–1883	4	,,
St. Paul's, 1845–1886	22	,,
Equatorial Atlantic, 1747–1878	43	,,
West Indies, Leeward Islands, 1839–1886	17	,,
South Atlantic, 1616–1875	10	,,
West Mediterranean, 1724–1865	11	,,
East Mediterranean, 1820–1886	20	,,
Gulf of Mexico and Caribbean Sea, 1751–1884	17	,,
Indian Ocean, 1818–1883	28	,,
North Pacific, east side, 1790–1885	22	,,
South Pacific, east side, 1687–1885	47	,,
North Pacific, west side, 1773–1681	14	,,
South Pacific, west side, 1643–1885	10	,,
East Indian Archipelago, 1796–1883	20	,,
Total	333	

The records generally are more frequent as we approach modern times, and, to some extent, for those seas and oceans where there have been the greatest number of observers. Dr. Rudolph regards all his records as referring to shocks of volcanic origin, and, if they agree with his definition of *Seebeben*, which are shakings originating in the ocean and propagated as elastic waves, we concur in his views.

2. *Sedimentation and Erosion.*

This section of the paper is a consideration of conditions which lead to the formation of sub-oceanic surfaces of instability which may yield by the continuation of the operations by which they are produced, or by seismic or volcanic actions.

The first fact to be noticed is that the materials resulting from marine denudation round coast-lines and subaërial denudation of continental areas are almost entirely deposited in the ocean, upon an area which is relatively small as compared with that from which they were derived, and therefore the rate of growth on littoral areas per superficial unit is on the average greater than the rate of loss similarly estimated on continents. We know from soundings that the materials derived from land are not always deposited to form a gently sloping submarine plain, but often to form surfaces with steep slopes. Thus, for example, the line of the Congo continued seawards is represented by a gully the sides of which have apparently been built up as a submarine *levée*. Materials thus accumulated under the influence of gravity and hydrodynamic action apparently

[1] *Trans. Seis. Soc.*, vol. xv. p. 73. [2] See p. 183.

result in contours which have reached limits of stability ready to yield as more materials accumulate, by facial slidings, by overloading, by changes in currents, by seismic action, and in other ways.

Forms of Stability.—On land we have many illustrations of natural curves of stability. A volcano mainly consisting of lapilli which have accumulated round a central orifice has a form dependent upon the density and strength as represented by resistance to crushing of its component materials. To increase the height of such a mountain, it would be necessary to increase the area of its base. The upper portion of Mount Fuji has a slope of 30°, but as we proceed downwards the slope becomes less and less until at last it is asymptotic to the plain from which it rises. The *average* slope of this volcano is 15°.

If, therefore, on the face of a bank formed by the accumulation of sediments, soundings, taken at points separated by one or more miles, indicate a certain inclination, it may be inferred that the steepest slope may possibly greatly exceed the quantity thus determined.

The only experiments bearing upon slopes of stability formed beneath water with which the writer is acquainted are a few made by himself. These experiments, which were made with sand and carried out in various manners, pointed to the following general results:—

1. Sediments deposited under the influence of currents accumulate in slightly flatter forms than those of similar materials built up on land.

2. Peaks, edges and corners of loose materials which may be fairly stable on land are beneath water, even when it is still, quite unstable, and quickly become rounded.

3. A mound or bank when thus rounded is very stable even under the influence of strong currents, but the unstable form may be quickly reproduced by the accumulation of new sediments.

The conclusions then are, first, if we find beneath water very short slopes of detrital materials, if they are 2° or 3° less than the angle at which similar materials are self-supporting on land, they have reached a limit of stability; and, secondly, average slopes over distances of one or more miles indicate the existence of much steeper slopes over shorter lengths.

Causes resulting in the Yielding of Submarine Banks.—Because it is not likely that submarine earthquakes the movements of which are felt round the world are the result of volcanic action whenever these are accompanied by sea-waves, it may be inferred that the latter have been produced by the dislodgment of vast masses of material from the faces of steep slopes. Illustrations of such changes will be given in the next section.

That intermittent facial sliding takes place on steep slopes during the accumulation of new materials is rendered likely by what we observe taking place on the faces of a mound of sand, submerged beneath water, as it grows upwards as an accumulation from a fine stream of sand descending from above.

Basal crush with horizontal displacement would only be expected to occur around the lower edges of slopes of great height; and as it is hardly reasonable to suppose that such slopes owe their form simply to the accumulation of sedimentary deposits, then the frequent origin of earthquakes in such localities indicates that the primary cause of crush or thrust is the result of yielding in rocky masses rather than that of detritus. When speaking of cable-interruptions it will be seen that some

of these have been attributed to the displacement of materials which have been loosened by the submarine escape of fresh water. Examples of springs of fresh water in bays and along coast-lines are numerous, whilst there is abundant evidence of the absorption of rainfall and even of rivers on continental areas, which in some instances it is suspected find an exit in the sea bottom. Granted the existence of sub-oceanic springs, we see in them at and near their exits a possible cause by which deposits may be loosened and landslips take place. Under certain conditions such dislocations might be expected to be periodical, following, for example, the rainy seasons. Ocean currents which fluctuate in direction and intensity, together with those of temporary character produced by the backing up of water during gales in bays, estuaries, and coasts, may also disturb the isostasy of submarine materials.

For details of these and other operations producing sub-oceanic change reference must be made to the writer's original paper.

3. *Cable Fracture.*

The fact that, on the level plains of ocean beds, cables lie for years and years without disturbance is another testimony to the facts brought together by geologists to show that the flat plains of ocean beds are regions where there is but little change. Directly, however, we approach sub-oceanic banks or the margins of continental slopes, although the depths may be abysmal, the fact that cables after interruption have to be broken away from beneath materials which hold them fast, indicates that regions of dislocation have been reached, and what is true for these great depths is also true for localities nearer land. Sometimes cables are bent and twisted, sometimes they are crushed. Now and again sections are recovered which, from the growth of shells and coral on all sides, show that they have been suspended. Others show that fracture has apparently been the result of abrasions, whilst the ends of wires, one of which is concave and the other convex, slightly drawn out, indicate that yielding has been the result of tension. Needle-pointed ends suggest electrolytic action;[1] but, although cable-interruption may occur in these and other ways, the explanation which best accords with the observations made during cable-recovery generally are those which attribute their dislocation to sudden displacement of the bed in which they are laid, or to their burial by the sliding down of materials from some neighbouring slope.

Sometimes it will be seen that earthquake movement and cable fracture have been simultaneous, whilst many instances will be given where an interruption has occurred at about the same time that an unfelt movement has been recorded on land. These latter records, which in the lists are marked with an asterisk, are unfortunately not numerous, and only refer to days between the following dates:—

1. Observations at Potsdam, Wilhelmshaven, Strassburg, Nicolaiew, Teneriffe, and in Japan. These, which include many of the writer's observations, are published in 'Beiträge zur Geophysik,' Band II., by Dr. E. von Rebeur-Paschwitz, March 27 to October 5, 1889; January 4 to April 27, 1891; February 23, 1892, to August 31, 1893.
2. Observations at Charkow by Prof. G. Lewitzky, August 4, 1893, to October 9, 1894.

[1] This may be due to electrolytic action between the zinc and iron of the sheathing wires, or to the cable having rested on a mineral deposit.

3. Observations by Prof. G. Vicentini, at Padua, February 1 to August 29, 1895.
4. Catalogues of Prof. P. Tacchini, January 1895 to October 16, 1896.
5. Observations at Shide, Isle of Wight, by John Milne, August 19, 1895, to May 1897.

Fracture of Cables in Deep Oceans.

The times of earthquakes are given in G.M.T. astronomical time. Noon = 24 hours.

North Atlantic.—Through the kindness of an engineer, whose experience in the laying and repairing of cables has extended over many years, I am enabled to give the dates at which various cables have become ruptured, or been restored to working order. The only case of alteration in depth which he noticed was during the repairs of November 1884, but this was not great. It seemed as if the picked-up cable had to be pulled from under a bank of earth which had slipped down from the eastern slope of the Newfoundland Bank.

The following is a table of North Atlantic cable-interruptions :—

North-eastern Slope of Flemish Cap.—(37° W. to 44° W. long.) July 1894 (about); June 1888 (about); September 1889; September 1881; June 10, 1894*; July 28, 4.40 A.M., 1885; April 18, 8 P.M., 1885; July 25, 8 A.M., 1887; June 1895.

Near South-eastern Slope of the Newfoundland Bank.—(46° W. and 50° W. long.) September 1887 (about); October 3, 9.15 P.M., 1884; October 4, 4.8 A.M., 1884; October 4, 4 and 8 A.M., 1884; September 1889.

An unfelt earthquake was recorded, June 11, 7h. 22m., 1894, very strong at Charkow.

A striking feature connected with these Atlantic troubles is that nearly all have occurred in deep water near to the base of the eastern slope of the Flemish Cap, 330 miles from St. John's, Newfoundland, or the south-eastern slope of the Newfoundland Bank. Off the Flemish Cap in lat. 49° N. and long. 43° E. there is a slope, in a distance of 60 miles, from a depth of 708 fathoms to 2,400 fathoms, or 1 in 35. Another slope, over a distance of 30 miles, is from 275 to 1,946 fathoms, or 1 in 17. Off the eastern side of the Newfoundland Bank, in a distance of 25 miles, the depth changes from 27 to 1,300 fathoms, indicating a slope of 1 in 19.

These slopes are all well within the limits at which from time to time yielding, due to bradyseismical thrust or secular crush, should be expected; and the further a cable can be kept away from the scene of such action, if we may judge from experience, the longer will be its life.

In one case only has the cause of failure been attributed to a landslide, which it is just possible was caused by, or accompanied with, seismic phenomena. A very significant fact is the case when three cables running in parallel lines about 10 miles apart broke, at points nearly opposite to each other, on the same straight lines. This was on October 4, 1884. At first the accidents were attributed to the grapnel of a cable vessel, but as no grappling was done then this hypothesis had to be abandoned. Because three cables broke apparently at the same time in the same locality, one inference is, that the cause resulting in rupture was common to all, and this may have been a sudden change in the configuration of the ocean bed. Such a change does not necessitate any alteration in depth, such as could be detected by sounding, but either a landslip along a line of considerable length or simply a line of fracture like that which was suddenly formed along the Neo valley in Japan in 1891.

When, on the American and English coasts, types of seismometers which will record the unfelt movements of the earth's crust have been

established, it seems likely that the cause of cable interruptions may be better understood. Because the fifteen repairs indicated in the previous table possibly cost half a million sterling, the advisability of localising areas that should be avoided, and that we should be able to attribute effects to their real cause, are evidently desiderata of great importance.

St. Louis—Fernando Noronha.—From a paper read at the Institution of Electrical Engineers by Mr. H. Benest, A.M.Inst.C.E., 'On some repairs to the South American Company's cables off Cape Verde in 1893 and 1895,' it seems that the St. Louis—Fernando Noronha cable has been twice broken. The first break occurred on December 26, 1892, about 130 miles from St. Louis du Sénégal, in a depth of 1,220 fathoms, at the time of a heavy gale. The tape covering for 140 fathoms was rubbed bare to the sheathing wires, but on one side only. The sheathing wires at the break were drawn out as if they had been broken in a testing-machine. The Fernando side of the break also showed the effects of rubbing, and the character of the fracture was similar to the other end. In picking up these two ends there was at first a strain in one case not exceeding 2·6 tons, and the other of 4 tons; but as the ends were approached this rose to about 6 tons, when the cable evidently cleared itself from some obstruction, and came easily on board.

Although we have here evidence of what may possibly have been a submarine landslip, I am not aware that at that time any disturbance was noted in Europe.

The second date is March 10, 1895. Here, again, great difficulty was experienced in breaking out the cable from beneath the mud, detritus, or whatever the materials were that had covered it. The position of this break was about 20 miles south-west from that of 1893.

On March 5, at 22 hours G.M.T., a very large unfelt disturbance was recorded in Europe, and one of moderate intensity at several places in Italy on May 10, at 10.4 P.M.

Mr. Benest holds the opinion that these fractures are connected with submarine river outlets and gully formations in the ocean beds. The gradients in the vicinity of the fractures vary from 1 in 34 (1° 30′) to 1 in 7 (8°).

Pernambuco—Cape Verde.—To the north-west of St. Paul's (lat. 2° 41′ 45″ N., and long. 30° 29′ 15″ W.), which is a volcanic centre, two cables broke simultaneously in a depth of 1,675 fathoms, indicating that the rupture was due to a widespread cause. This was on September 21, 1893. Here, in the deep ocean, this was the only failure in nineteen years.

Madras—Penang and *Aden—Bombay.*—These interruptions are referred to on pp. 198, 199.

Interruptions to Cables on or near to Sub-oceanic Continental slopes.

West Coast of Central and South America.—As illustrative of conditions which may exist round many parts of the west coast of South America, where there have been sudden and gradual upliftings of the land within historical time, a portion of a chart showing contours near to the mouth of the river Esmeralda is reproduced. The soundings are in fathoms. Those in ordinary figures are from information received prior to June 1895, whilst those in larger type are from soundings taken in March 1896. Changes from 13 or 20 fathoms to upwards of 200 fathoms in this short interval of time are certainly remarkable; and as the position of the cable-repairing vessel 'Relay,' belonging to the Central and South American Telegraph Company, which made the observations, was ensured by cross-bearings on the land, their general accuracy cannot be doubted.

The figures surrounded by a circle were taken many years ago, and

are probably no longer correct. Off the shore, in a distance of 3 miles, there is a depth of 200 fathoms, indicating a slope of 1 in 15, whilst at distances of 10 miles from shore, over a length of 1 mile, slopes of 1 in 3 may be found.

We have evidently here many instances of recent change in sub-oceanic form, and at the same time illustrations of conditions where considerable instability might be expected, and cable interruptions might therefore frequently occur. It will be noted, by reference to the map, that the position of fractures which have taken place are grouped near to the base of these steep slopes, and in this respect follow the rule of similar occurrences in the North Atlantic.

The following is a list of certain interruptions which have taken place off the coasts under consideration :—

La Libertad—Salina Cruz.—November 25, 1890.

Panama—San Juan del Sur.—June 4, 1889* ; July 31, 1889*.

Sta. Elena—Buenaventura.—This section is laid off the mouth of the river Esmeralda, at which point many breaks have occurred. Lat. 58′ 20″ N., long. 79° 41′ 25″ W. August 30, 1890; January 25, 1891* ; February 13, 1892; December 5, 1893* ; December 6, 1893* ; December 14, 1893* ; December 20, 1893.*

Paita (Peru)—Sta. Elena (Ecuador).—This section passes Talara point, where many breaks have occurred. Lat. 4° 29′ S., long. 81° 17′ W. September 1892 ; May 19, 1883 ; September 3, 1886 ; May 15, 1889* ; March 31, 1891* ; April 9, 1891* ; May 14, 1892*.

Mollendo—Chorillos (Peru).—This section crosses the gully off Pescadores point, lat. 16° 24′ S., long. 73° 18′ W. February 23, 1884 ; March 24, 1884 ; April 5, 1884 ; June 13, 1884 ; January 30, 1886 ; August 13, 1886 ; August 16, 1887 ; March 25, 1887 ; December 10, 1887, supposed to have been broken by an earthquake ; December 11, 1888 ; February 21, 1890 ; March 15, 1890 ; March 30, 1891* ; June 4, 1895* ; October 16, 1892*, supposed to have been broken by an earthquake.

Arica—Mollendo.—May 9, 1877, by an earthquake ; July 15, 1887 ; before June 24, 1891 ; August 13, 1891 ; June 6, 1895*, shore end broken by waves.

Iquique—Arica.—May 9, 1877, by earthquake ; May 7, 1878, by an earthquake ; June 12, 1895*, shore end broken by waves.

Caldera—Antofagasta.—July 7, 1886.

Valparaiso, Serena.—July 26, 1877 ; August 15, 1880, by earthquake ; July 8, 1885 ; before August 19, 1891. July 4, 1895*, by landslide or earthquake.

The *unfelt* earthquakes which were noted in or near Europe were as follows :—

January 25, 1891, 5·01h. A small disturbance was recorded at Teneriffe.

March 26, 1891, 13·6h. to 14·8h. There was an earthquake of moderate intensity noted in Teneriffe.

May 15, 1892. At 2·9h. at Strassburg, and at 3·7h. at Nicolaiew, there was a feeble shock. It is, however, possible that this earthquake may have had its origin at Stavanger, in Norway.

October 13, 1892. At 17·07h., and October 17, at 11·88h. at Strassburg.

December 16, 1893. At Charkow at 13h. 13m. there was a strong disturbance.

June 4, 1895. At Padova at 18h. 23m., large disturbance.

July 5, 1895, 5h. 32m. At Padova, origin evidently at a great distance.

Whether these seven unfelt movements recorded on the eastern side of the Atlantic were connected with seismic disturbances on the western side of South America leading to cable interruptions, it is impossible to speak with confidence until we know the *hours* at which these interruptions took place. In the meanwhile, all that we can say is, that it is worthy of note that out of fourteen cable interruptions, seven of them took place about the times when delicately suspended instruments in or near Europe were set in motion. Six interruptions took place when

earthquakes were felt, whilst others were caused by landslips, which in turn may have been the result of mechanical shaking. On certain sections, as for example that connecting Arica and Mollendo, fractures have only taken place in certain months, which in this instance are June, July, and August. Restrictions like this suggest that the cause of fracture has been due to landslips brought about by the escape of fresh water beneath sea-level, the action of currents, or other sub-oceanic phenomena having seasonal maxima.

The interruptions off Pescadores Point (16° S. lat.), although, when recovering cables, branches of almost petrified trees have been brought to the surface, Mr. R. Kaye Gray attributes to the great unevenness of the bottom, there being in that neighbourhood submarine hills 3,000 and 4,000 feet in height.

The following notes bearing upon the above sections were kindly drawn up by Mr. W. E. Parsoné, who has been engaged in cable work on the west coast of South America :—

Arica—Mollendo Section.—This section was laid in 1875. On the night of May 9, 1877, while the cables between Arica and Lima were being used for direct working, a very distinct shock of earthquake was felt by the operator in the Lima office at about 10.30 P.M., during receipt of a message from Arica, and communication ceased a few seconds later. The intermediate station of Mollendo afterwards reported that the shock was also felt there, and at about the same time, and that they were unable to communicate with Arica. Mr. Parsoné located the rupture of the Arica—Mollendo section as close to the shore at Arica, and proceeded by first opportunity to that place, where it was found that a violent earthquake shock on May 9, 1877, had been accompanied by a tidal wave of unusual severity, which had completely wrecked the greater portion of the town. The sea-front and harbour had suffered enormous damage, the iron pier having been washed away, and practically all the craft in the port having parted their moorings or foundered. In undertaking the repair, tons of anchor-moorings and material were picked up with the cable, which had been considerably dragged out of position and twisted for a considerable distance from the shore. Communication on this section was restored on May 24, 1877, and worked without interruption until it was permanently repaired by renewing a portion of the shore-end and intermediate cable on November 17, 1878.

Iquique—Arica Section.—This section was laid in 1875. On May 7, 1878, a severe shock of earthquake was experienced in the neighbourhood of Iquique, after which the cable connecting that place with Arica was found to be interrupted. Mr. Parsoné located the rupture at 6 knots from Iquique on the intermediate cable in 60 fathoms of water, and, after considerable difficulties working with barges, there being no repairing-ship obtainable, succeeded in lifting the cable on the spot. Both ends were recovered, and it was found that the cable (intermediate) had snapped clean through, the compound on either side of the break being undisturbed, except at, say, a distance of 18 inches on either, where the sheathing wires had made one complete turn. There the compound had sprung, and some of the strands parted, and the sheathing wires compressed out of position. But for these comparatively slight indications of the enormous force which must have been exerted to make so clean a break in heavy intermediate type, the cable was in no way damaged, the rest of the cable being in as good condition as the day it left the factory. The earthquake, which was undoubtedly the direct cause of the rupture, was said to have a direction from south-west to north-east, and it was noticed with much surprise that the base of the high cliffs on the fore-shore bore marks of recent disturbance at a spot bearing due north-east from the position of the break. The disturbance referred to had the appearance of a recently formed cavern or tunnel—a few feet above the beach where the base of the hard rock was met—as if some enormous piece of artillery had been fired point-blank into the rock, and this had also caused a falling away of the surface rock above the opening, which peels off in layers like decomposed slate. We could not land at the place to examine it more closely on account of the surf and rocks, but attempted to do so by clambering and crawling over the headland of rock; but large thin sections of decomposed surface slipped

away with us continually, and we had to give up the attempt. Communication was restored with a piece of deep-sea cable and permanently repaired with the s.s. 'Retriever' on November 21, 1878.

La Serena—Valparaiso Section.—This cable was laid in 1876, and interrupted off the Limaree River on July 26, 1877, as was thought, by floods from the river, although in its normal condition it is practically a dry bed before it reaches the sea.

This section was again interrupted on August 15, 1880, by an earthquake; and the same section was again interrupted by a landslip on July 4, 1885, presumably due to an earthquake.

Mollendo—Chorillos Section.—This cable was laid in 1875, and was frequently interrupted off Pescadores Point to the north of Mollendo, where considerable inequality of depth is experienced, due presumably to the channels of an extinct or subterranean river, whose estuary may now be some miles at sea, and create periodical submarine convulsions at great depth and at, say, 40 or 50 knots from the coast. In any case, all difficulty has ceased in this locality, since the cable has, for a considerable length, been diverted to close inland and laid as close to the shore as it was safe for a ship to get.

This section was also broken in two different places by an earthquake which occurred on December 10, 1887.

East Coast of South America.—The geological and topographical conditions on the east coast of South America are strikingly different from those met with on the west coast. On this latter coast the land plunges rapidly downwards beneath the sea, as a slope produced by bradyseismic thrust and folding, whilst on the former, when measured over long distances, the slope is gentle, indicating an absence of orogenic activities. Although the land is generally continued seawards at a low angle by the deposition of sediments and the scouring action of currents, here and there declivities may have been produced by such epigenic actions.

On the following sections interruptions have been rare or have not occurred:—

Maldonado—Montevideo.—Since 1875.
Santos—Chuy.—Since 1892.
Chuy—Maldonado.—Since 1875.
Rio Grande do Sul—Chuy.—Since 1875.

From these sections, which lie on the northern side of the Rio de la Plata estuary, as we proceed northwards interruptions have been more and more frequent. They are as follows:—

Montevideo—Buenos Ayres.—October 12, 1889.

Sta. Catharina—Rio Grande do Sul.—June 16, 1890.

Santos—Sta. Catharina.—March 12, 1890.

Montevideo—Rio Grande do Sul.—April 25, 1889; June 11, 1889*; December 4, 1889; May 4, 1890; December 4, 1891.

Chuy—Montevideo.—June 27, 1892; July 10, 1892* (*restored*); November 11, 1892 (date of *interruption* not recorded).

Rio de Janeiro—Santos.—April 16, 1889; April 5, 1890; December 24, 1890.

Bahia—Rio de Janeiro.—January 31, 1889; September 3, 1889*; September 21, 1889*; July 24, 1891; July 31, 1891; September 4, 1896.

Pernambuco—Bahia.—April 1, 1889; July 20, 1889; July 14, 1891.

Ceara—Pernambuco.—April 8, 1890; March 14, 1891*; September 1, 1893*; January 12, 1895; March 3, 1896; March 4, 1897*.

Maranham—Ceara.—May 22, 1889*; April 29, 1890; January 20, 1891; January 28, 1891; March 4, 1891*; March 8, 1891*; November 25, 1891; October 11, 1892*; February 12, 1894*; March 6, 1894*; November 25, 1894; April 28, 1896; December 2, 1896.*

Para—Maranham.—September 6, 1888; November 2, 1888; May 22, 1889*; December 27, 1889; January 10, 1890; July 24, 1890; January 12, 1891; October 19,

1891; December 2, 1891; January 19, 1892; October 15, 1892*; March 20, 1893*; September 1, 1893*; March 24, 1894*; July 23, 1894*; November 1, 1894; November 10, 1894; November 15, 1894; January 7, 1895; February 9, 1895*; October 10, 1895*; December 13, 1895*; December 18, 1895*; July 9, 1896*; August 6, 1896*; October 8, 1896*; May 5, 1897.*

In the above list the thirty-one interruptions marked with an asterisk took place whilst horizontal pendulums were in operation in or near Europe.

The European observations were as follows :—

September 18, 1889. At Potsdam, 6·92h. to 9·3h., there was a large disturbance, which suddenly became great at 7·87h. At Wilhelmshaven the disturbance lasted from 7h. to 9·5h. The origin is unknown.

September 5, 1889. At Potsdam there was a heavy disturbance at 22·67h., with a sudden increase at 23·08h. At Wilhelmshaven similar phases are at 22·5h. and 23·08h. Large disturbances also with unknown origin were noted on August 29 at 18·48h.

October 9, 1892. At Strassburg and Nicolaiew, at about 2·45h. and 2·70h.

March 3, 1891. At Teneriffe, earthquake at 1·79h. Origin unknown.

May 21, 1889. At Potsdam, a heavy disturbance at 10·55h. to 11·1h. Origin unknown.

March 20, 1893. At Strassburg and Nicolaiew, at 5·18h. and 5·27h. At this time there was an earthquake in Catania.

October 13, 1892. In Strassburg 17·07h. to 17·78h. An earthquake on the Donau.

September 1, 1893. At Charkow at 9.35 A.M.

February 12, 1894. At Charkow, a strong disturbance at 1.35.

March 24, 1894. At Charkow, about this time, exceedingly heavy disturbances were recorded. From 17h. 35m. on the 21st to 2h. 48m. on the 22nd; from 9·35h. on the 22nd to 3·35h. on the 23rd; and on the 24th, from 0h. 26m. to 1h. 2m.

July 22, 1894. At Charkow, from 11·35h. to 17·35h.

October 9, 1895, at 13h. 26m. Slight.

July 8, 1896, at 14h. 54m. and 17·46. At Shide.

October 6, 1896, at 21·51h. At Shide.

May 5, 1897, at 10·44h. At Shide.

December 2, 1896, at 10 to 11 A.M. At Shide.

Inasmuch as two of the interruptions took place on May 22, 1889, and two on September 1, 1893, which closely correspond with the unfelt but heavy earthquake in that year, we may say that out of twenty-nine interruptions sixteen of these have approximately coincided with the times at which earthquakes with unknown origins have been recorded in Europe.

Because on the Para—Maranham [1] section interruptions have been frequent in October, November, and December, and on the Maranham—Ceara section in November and in March, in searching for the cause of these interruptions we should look to variations in ocean currents or phenomena with a seasonal change.

West Coast of Europe and Africa.

Mediterranean Lipari—Milazzo Sea.—December 1, 1888; March 30, 1889*; September 15, 1889*; February 9, 1893.*

Zante—Canea.—March 29, 1885.

[1] 'The Para—Maranham cable is, I believe,' a friend writes me, 'laid on a shallow muddy bottom, the mud being so fluid that it is said that a schooner with a fair wind can make a good passage when half in mud and half in water.' If this is so, then the Amazon floods may have much to answer for in connection with cable-interruption.

Patras—Corinth.—September 9, 1888; August 25, 1889* (two interruptions).

The earth-movements which were observed were as follows:—

March 28, 1889. At 7·35h. at Wilhelmshaven, fairly large.

September 13, 1889. At 5·50h. at Potsdam and from 7h. to 9·5h. at Wilhelmshaven.

February 9, 1893. At Strassburg 6·23h. to 8·48h., and at Nicolaiew 6·19h. to 8·07h., heavy movement. The epicentre possibly near Samotrace. Two other earthquakes were noted on this day.

August 25, 1889. At Potsdam at 7·62h. and at Wilhelmshaven from 7·53h. to 9h., a large disturbance. Epicentre near Patras.

The Lipari—Milazzo fractures took place in depths of from 400 to 650 fathoms 2 or 3 miles distant from Vulcano, about north-east from Solfatore.

The Zante—Canea interruption occurred about 5 miles west by south off Sapienza Island, in a depth of 1,500 fathoms with a clay bottom. Soundings varied as much as 250 fathoms in the length of the ship, and from 1,350 to 1,834 fathoms in half a mile.

The first of the Patras—Corinth breaks occurred about 2 miles north of Akraia, in mud at a depth of 197 fathoms, whilst one of the second interruptions took place in the same locality, in depths varying between 408 and 270 fathoms within a mile, and the other, in cable No. 2, within half a mile south of Morno point.

Mr. W. G. Forster, writing in the 'Transactions of the Seismological Society,' vol. xv., respecting these districts, tells us that after the Filiatra shock in 1886 it was found, by the broken cable 30 miles away, that some four knots of the same had been covered by a landslip, whilst the depth of the water had increased from 700 to 900 fathoms. In 1867, after the destruction of Cephalonia, the soundings taken after the shock were different from those taken before. Again, on September 9, 1888, at 5.4 P.M., the town of Vostizza, in the Gulf of Corinth, was destroyed, and simultaneously the cable between Zante, Patras and Corinth was interrupted. The cause of this, as deduced from soundings and the appearance of the fractured cable, appears to have been either a sudden tautening caused by the sweeping down of a mass of clay from a 100-fathom bank to a 300-fathom bank, or the actual yielding of the bed on which the cable lay.

In 1889 a second cable was laid down in the Gulf of Corinth, but this, when it had been down about three months, was, together with the 1884 cable, fractured at the time of an earthquake on August 25 at 8.51 P.M. The 1889 cable seemed to have been smashed by the movement of a mass of material about a mile in length, whilst the 1884 cable was broken at two points by a slip on a 10 to 450 fathom bottom.

In the districts considered by Mr. Forster, there are, as he points out, great irregularities in submarine contours, the depths within short distances changing from 50 to 300 and then to 1,600 fathoms. By the deposition of silt, and the undermining of steep slopes by bottom currents, the exit of underground springs and even rivers, overhanging shelves, tottering and precipitous rocks, and other unstable arrangements, may suddenly give way and cables suffer rupture.

The facts are that the sub-oceanic contours are such that they might be expected to be unstable, and that these contours, at the time of earthquakes, have suddenly been changed. In one instance there has been an

increase in depth of over 2,400 feet, and in another of 1,200 feet; whilst in the case of the 1889 disturbance, eleven and a half minutes later, unfelt earth-waves of considerable magnitude were recorded at Wilhelmshaven, 1,732 kilometres distant. Similar unfelt movements have also been recorded at distant places at about the time when cable-interruptions took place, *in every instance* where we have been able to make comparisons. The conclusion, then, is that in this region earthquakes occur, producing beneath the ocean what is equivalent to the landslips which similar movements produce on land.

Bay of Biscay.—About 1875 the Direct Spanish cable was broken about 150 miles north of Bilbao by what seemed to be a submarine landslip, which may have been produced by an undercurrent produced by the piling up of the surface waters under the influence of a westerly gale. The soundings showing the neighbourhood of the interruption indicate slopes of 1 in 7 and even 1 in 3, and it is therefore a district in which landslides and dislocations might be expected to occur. From Mr. R. Kaye Gray I learn that the 1872 Bilbao cable broke down periodically—usually in the month of March, with or after a heavy north-west gale. This took place about 30 miles to the north of Bilbao, and, when repairing, it was invariably found that 4 or 5 miles had been buried. The cause of these interruptions was attributed to a heavy submarine current caused by the piling-up of surface water, cutting the prolongation of a river-bed with steep walls which, when undercut, fell in masses to bury the cable.

St. Thomé—St. Paul de Loanda.—Interruptions which have been noted on this section were as follows:—

January 22, 1892; September 13, 1892*; November 24, 1892*; February 17, 1893*; April 11, 1893*; May 30, 1893*; February 5, 1894*; January 22, 1895*; January 15, 1896*; May 2, 1896*; June 15, 1896.*

The dates on which unfelt earthquakes were recorded were as follows:—

September 13, 1892. At Strassburg a very large disturbance from 9·54h. to 13·31h. Origin unknown.

February 16, 1893. At Strassburg at 0·08h. Origin possibly in Japan.

April 11, 1893. At Strassburg and Nicolaiew, 18·58h. to 19h. Moderate. On April 8 at these stations there was a heavy movement from 1·87h. to 4·17h. Origin unknown.

May 30, 1893. At the above stations from 4·33h. to 5·32h.; a great movement.

February 5, 1894. At Charkow from 4h. 54m. to 10h. 34m. there was a strong movement.

January 18, 1895, 2h. 37m. At many places in Italy.

January 15, 1896, 7h. 10m. At many places in Italy.

May 2, 1896, 1h. 20m. Strong through Europe.

June 13, 1896, 14h. 54m. Strong through Italy.

June 14, 1896, 22h. 46m. Strong through Italy and at Shide. Origin, Pacific Ocean.

We have therefore ten cases of interruptions on or near to the dates of nine of which large earthquakes were recorded. It is difficult to imagine that this particular district should be characterised by any seismic activity, but it seems possible that, if it is a district where sediments rapidly accumulate to attain an unstable form, these might from time to time give way under the influence of earth-waves originating at a great distance.

On this particular section Mr. R. Kaye Gray points out that, from

the mouth of the Congo, extending seawards, there is a difficult gully to cross, the walls of which are 2,000 feet in height! Although the gully widens towards the west, this height is maintained for a considerable distance. The shallowest water is found along the edges of this gully, which therefore has a transverse section not unlike that of a river bounded by a naturally formed levée.

The East Coast of Africa.—The following are interruptions noted in various cable sections along the east coast of Africa :—

Mozambique—Zanzibar.—February 1, 1885; April 2, 1885; September 26, 1894*.

Delagoa Bay—Durban.—October 15, 1890; November 18, 1890; December 10, 1894; January 20, 1896*; July 13, 1896*.

Mozambique—Delagoa Bay (Lorenzo Marquez).—November 11, 1890; November 18, 1890; January 5, 1893*; January 25, 1893*; June 9, 1895*; December 24, 1896.*

Zanzibar—Mombasa.—December 20, 1890; January 25, 1892; September 4, 1894*; September 26, 1894*; March 6, 1896*; August 23, 1896*; September 23, 1896*.

Aden—Zanzibar.—January 8, 1890; May 11, 1891; December 5, 1891; February 20, 1893*; August 9, 1893*; December 21, 1894; September 2, 1895*; December 24, 1895*; January 27, 1896*; March 16, 1896*; March 23, 1897 (?).*

With the nineteen interruptions marked with an asterisk, there are eleven instances where these may have corresponded with the records of unfelt earthquakes. Approximate coincidences with earth-movements are as follows :—

January 22, 1893, at 19·87h. A weak disturbance was noted at Nicolaiew and Strassburg.

September 1, 1894, from 1h. 43m. to 4h. 21m. Moderate at Charkow.

September 25, 1894, 16h. 49m. to 17h. 8m. At Charkow.

February 20, 1893, from 19·23h. to 19·78h. At Strassburg small, origin in Japan.

August 9, 1893, from 17h. 11m. to 19h. 4m. At Strassburg moderate.

March 3, 1896, at 16h. 33m. Recorded through Europe.

August 21, 1896, at 10h. 0m. Recorded at Padua.

September 2, 1895, at 1·3h. to 9·6h. and 19h. At Shide.

March 15, 1896, at 19h. 36m. At Shide.

September 21, 1896, at 16h. 53m. Recorded through Europe.

March 23, 1897. At Shide at 4·29h., slight.

Sir James Anderson, in 1887, speaking about the interruptions off the river Rovuma (11° S. lat.), remarks that, so far as soundings showed, there was an even bottom and all that could be desired as a bed on which to place a cable, yet every year the cable broke. The broken ends suggested that the cable had been suspended until it snapped. Although the cable was shifted further out, and then closer in, it still broke. This happened eight times, and it was noticed that the interruptions occurred at about the same time of the year. Seven of these breaks are fairly on the same line, and Sir James's suggested explanation of this cause was that the time when the interruptions occur is at the termination of the rainy season in the African mountains, at which time fresh-water springs take away the bottom on which the cable lies, and leave it suspended.

Mr. John Y. Buchanan suggests that sometimes a cable may be broken in consequence of its slowly subsiding through ooze, until the catenary strain becomes so great that it eventually snaps.

Aden—Bombay.—Interruptions noted on this section were the following :—

July 11, 1881; June 3, 1885; July 27, 1885; July 11 1888 August 11, 1888.

On the second and last of the above dates the two cables connecting Aden with India were simultaneously broken, and the traffic between India, Australia, and the East had to pass over the land lines of Russia, Persia, and Turkey. The fractures took place on an even bottom a few hundreds of miles from Aden. At the time of the 1885 interruption, a fearful cyclone was raging at Aden, and it is therefore possible that the ruptures may be attributed to causes similar to those which seem to have operated on the Bilbao cables (p. 191). The place of fracture was 119 nautical miles from Aden, 20 to 25 miles south of the Arabian coast, at a depth of 870 to 990 fathoms, on an even bottom of mud.

Penang and Madras.—Interruptions noted on this section have been as follows :—

May 12, 1873; November 15, 1875; March 28, 1876; November 9, 878; April 22, 1880; January 31, 1881; June 6, 1883; November 15, 1883; June 13, 1884; September 2, 1886; November 2, 1886; November 14, 1886; September 22, 1888 (?); May 13, 1890.

On the above dates horizontal pendulums or the equivalent instruments were not in operation, but that these interruptions were partly due to sub-oceanic change may be inferred from the fact pointed out by Sir John Pender in the 'Electrical Review' of May 23, 1890, who says that nearly all the interruptions on this line have taken place on very bad ground near the Nicobar Islands.

The following completes the list of interruptions on far eastern lines :—

Rangoon—Penang.—September 4, 1886; May 13, 1890.

Singapore—Penang.—November 20, 1873; August 7, 1876; November 8, 1876; December 20, 1876; July 20, 1877; October 19, 1877; September 30, 1878.

Batavia—Singapore.—March 31, 1873 (?); May 20, 1874 (?); August 13, 1874; August 18, 1874; December 14, 1874; September 2, 1875; November 5, 1875; May 9, 1876; June 28, 1876; October 25, 1876; February 27, 1877; September 28, 1877; November 9, 1877; January 22, 1878; May 2, 1878; August 31, 1878; October 28, 1878; December 28, 1878; September 20, 1879; December 3, 1883.

Port Darwin and Java (Banjoewanji).—June 21, 1872; April 27, 1876; November 8, 1877; September 27, 1878; May 29, 1879; July 4, 1879; March 5, 1883; March 10, 1883; April 6, 1883; October 22, 1883; June 29, 1888 (two cables broken); October 10, 1888 (both cables broken); October 22, 1888 (both cables broken); July 11, 1890* (three cables broken, one being to Roebuck Bay); February 23. 1893*; March 22, 1893*; September 27, 1893*; October 25, 1893* (two cables broken);[1] October 26, 1893*.

The horizontal pendulum records are as follows :—

February 22, 1893. At Strassburg, 11·28h. to 11·78h.; also at Nicolaiew. Moderate.

March 20, 1893. At Strassburg, 5·18h. to 5·53h.; also at Nicolaiew. Moderate. Origin probably in Zante.

September 11, 1893. At Charkow, 16h. 13m. to 17h. 50m.

October 22, 1893. At Charkow, 6h. 53m. to 8h. 14m.

The two fractures of June 29, 1888, took place 20 and 25 miles south by west of Mount Dodo, Sambawa, where depths vary from 734 to 1,130 fathoms. Sir John Pender, at the ordinary general meeting of the Eastern Extension Australasia and China Telegraph Company,[2] says that it was found that these breaks resulted from 'volcanic' action; and, curiously

[1] See *Electrician*, November 3, 1893. [2] *Ibid.*, October 12, 1888.

enough, when the cables were recovered, all sorts of things, even the roots of trees, were found attached to them. The whole thing seemed to be a great upheaval of nature. From the same paper, August 20, 1888, we learn that these two interruptions took place at points widely separated. In Port Darwin time, the fractures took place on June 29, at 10.40 P.M. The three interruptions of July 11, 1890, took place, in Banjoewanji time, at 1.35 A.M., on a rough, uneven bottom, between Tafel Hoek (Bali) and Balambangan Point, Java, where the depths vary from 155 to 927 fathoms. The duplicate cable was broken in three places, and overlaid about 65 miles from Banjoewanji. The three cables run along two sides and near the bottom of a gully separating Baly from Java, and are about 7 miles apart. They practically broke on one line, and the cause was 'volcanic' action.[1] In this instance, as in that of June 30, 1888, the submarine displacements extended over an unusually wide area ; and, when we refer to a chart, it is seen that at a distance of 9 miles in a south-west direction from Tafel Hoek there is a depth of 1,180 fathoms, indicating a slope of 1 in 7.

The only interruptions which can be compared with the records of horizontal pendulums are the last five, whilst the time of the interruption of March 22, 1893, is not known. The mean Greenwich times and dates at which the remaining four took place in 1893 are as follows :—

1. February 22, between 4h. 20m. and 16h. 20m.
2. September 12, 12h. 20m.
3. October 24, 17h. 5m.
4. October 26, 3h. 0m.

The conclusion is that only the first of these four interruptions took place when an unfelt earthquake was recorded in Europe, but similar disturbances were noted on September 11 and October 22.

The following table is a comparison of the days and hours when earthquakes were felt in Java, with the times at which cables were interrupted :—

Shocks felt in Java and Sumatra in *approximate* G.M.T. (Batavia time — 7 hours)	Date and G.M.T. of cable-interruptions
1872, June 16, 12h. to 14h	June 21.
1876, April 23, 10h. 15m. Sumatra . . .	April 27.
1877, November 3 to 4	November 8.
1878, September 21, 19h. 30m. Sumatra .	September 27.
1879, without records.	
1883, March 6, 4h. 45m. Sumatra . . .	March 5.
,, October 18, 17h. 0m. Banjoewanji .	October 22.
1888, June 29, 21h. 33m. Batavia . . .	June 29, 3h. 40m.
,, October 8, 12h. 18m. Series of shocks ,, ,, 9, 12h. 26m.	October 9.
,, ,, 21, 12h. 5m. Light shock . .	October 22.
1890, July 10, 16h. 50m. to 19h. 40m. Series of shocks, some heavy. Java	July 11, 6h. 35m.
1893, February 23, 15h. 15m. Java. . .	February 23, 4h. 20m. and 16h. 20m.
,, March 22, 13h. 32m. Light. Java .	March 22 (time unknown).
,, September 9, 22h. 57m. Moderate. Java	September 27, 12h. 20m.
,, October 23, 9h. 53m. Fifteen shocks, very heavy. Java ,, October 25. A light shock . .	October 25, 17h. 25m.

[1] See *Electrician*, October 24, 1890, vol. xxv.

For the interruptions of cables on June 29, 1888, and July 10, 1890, we have the assurance of those connected with their management that

A Tabular Arrangement of the Foregoing Interruptions.

Name of cables	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
North Atlantic	—	—	—	1	—	3	3	—	3	4	—	—	14
St. Louis—Fernando Noronha .	—	—	1	—	—	—	—	—	—	—	—	1	2
Pernambuco—Cape Verde .	—	—	—	—	—	—	—	—	1	—	—	—	1
Luhibestad—Salina Cruz .	—	—	—	—	—	—	—	—	—	—	1	—	1
Panama—San Juan del Sur .	—	—	—	—	—	1	1	—	—	—	—	—	2
Sta. Elena—Buenaventura .	1	1	—	—	—	—	—	1	—	—	—	4	7
Paita—Sta. Elena . . .	—	—	1	1	3	—	—	—	2	—	—	—	7
Mollendo—Chorillos . .	1	2	4	1	—	2	—	2	—	1	—	2	15
Arica—Mollendo . . .	—	—	—	—	1	2	1	1	—	—	—	—	5
Iquique—Arica . . .	—	—	—	—	2	1	—	—	—	—	—	—	3
Caldera—Antofagasta . .	—	—	—	—	—	—	1	—	—	—	—	—	1
Valparaiso—Serena . .	—	—	—	—	—	—	3	2	—	—	—	—	5
Montevideo—Buenos Ayres .	—	—	—	—	—	—	—	—	—	1	—	—	1
Sta. Catharina—Rio Grande do Sul	—	—	—	—	—	1	—	—	—	—	—	—	1
Santos—Sta. Catharina . .	—	—	1	—	—	—	—	—	—	—	—	—	1
Montevideo—Rio Grande do Sul	—	—	—	1	1	1	—	—	—	—	—	2	5
Chuy—Montevideo . .	—	—	—	—	—	1	1	—	—	—	1	—	3
Rio de Janeiro—Santos . .	—	—	—	2	—	—	—	—	—	—	—	1	3
Bahia—Rio de Janeiro . .	1	—	—	—	—	—	2	—	3	—	—	—	6
Pernambuco—Bahia . .	—	—	—	1	—	—	2	—	—	—	—	—	3
Ceara—Pernambuco . .	1	—	3	1	—	—	—	—	1	—	—	—	6
Maranham—Ceara . . .	2	1	3	2	1	—	—	—	—	1	2	1	13
Para—Maranham . . .	4	1	2	—	2	—	2	2	2	4	4	4	27
Lipari—Milazzo . . .	—	1	1	—	—	—	—	—	1	—	—	1	4
Zante—Canea	—	—	1	—	—	—	—	—	—	—	—	—	1
Patras—Corinth . . .	—	—	—	—	—	—	—	1	1	—	—	—	2
St. Thomé—St. Paul de Loanda	3	2	—	1	2	1	—	—	1	—	1	—	11
Mozambique—Zanzibar . .	—	1	1	—	—	—	—	—	1	—	—	—	3
Delagoa Bay—Durban . .	1	—	—	—	—	—	1	—	—	1	1	1	5
Mozambique—Delagoa . .	2	—	—	—	—	1	—	—	—	—	2	1	6
Zanzibar—Mombasa . .	1	—	1	—	—	—	—	1	3	—	—	1	7
Aden—Zanzibar . . .	2	1	1	—	1	—	—	1	1	—	—	3	10
Aden—Bombay . . .	—	—	—	—	—	1	3	1	—	—	—	—	5
Penang—Madras . . .	1	—	1	1	1	2	—	—	2	—	5	—	13
Rangoon—Penang . . .	—	—	—	—	1	—	—	—	1	—	—	—	2
Singapore—Penang . .	—	—	—	—	—	—	1	1	—	1	2	1	6
Batavia—Singapore . .	1	1	1	—	3	—	—	3	3	2	2	3	19
Port Darwin—Java . .	—	1	3	2	1	2	2	—	2	5	1	—	19
	21	12	25	14	19	19	23	16	28	20	22	26	245

the cause was volcanic or seismic, whilst the actual or close coincidence in the dates at which the remaining interruptions have taken place with the days on which earthquakes have been felt leads to the belief that the Port Darwin—Java section has suffered more from the effects of sudden sub-oceanic change than from any other cause. The European records of February 22 evidently refer to the disturbance which caused the interruption on that date in Java between the hours 4·20h. and 16·20h.

The above table is a list of the thirty-eight lines just discussed, along which one or more cables are laid. Since these lines were esta-

blished, the number of interruptions which have occurred have been at *least* 245. For certain lines it would appear that fractures were more frequent at one season than at others, and that therefore a proper analysis of the table or its parts—such, for example, as those to which earthquake statistics have been subjected—might lead to the discovery of periodicities in cable-interruptions. Unfortunately, because the material in our possession is yet so meagre, such discussions must for the present be reserved.

Out of the 245 breaks, 87 of them, each marked with an asterisk, occurred at the times when instruments were in operation which would record unfelt earthquake effects. Fifty-eight of the 87 cable-interruptions occurred at or about the times when Europe was agitated by these unfelt movements. The fractures accompanying earthquake, or, as it is sometimes called, volcanic movement—which could be felt, and which in two instances caused destruction on neighbouring shores—were at least 10 in number, which may be raised to 24 by including the Java records. In three of these instances, two or three cables were broken simultaneously. With the latter the submarine dislocations extended over a wide area; in the Gulf of Corinth great changes in ocean depth were brought about, and from this latter place we know the motion to have radiated so that a few minutes after the interruption well-defined diagrams of earth-waves were obtained at localities 1,000 miles distant, at places where no movement could be felt.

Instances like the latter clearly establish a connection between cable-interruptions, earthquake-motion which has been felt, submarine dislocation, and the records of horizontal pendulums in distant localities. This being the case, and because earthquake-motion cannot be felt at great distances from its origin, it is reasonable to conclude that the records of unfelt earthquakes which approximately coincide in time to those at which cables have been interrupted may sometimes indicate that submarine geological changes have accompanied seismic efforts.

Although certain conclusions arrived at in this paper are definite, until the materials necessary for analysis can be obtained, others remain matters of inference. The records of interruptions for the lines mentioned are, we have reason to believe, incomplete. The horizontal pendulum records with which to make comparisons have not only been few in number, but, because they are confined to Europe, could only be expected to throw light upon disturbances originating at a great distance, which were exceptionally large. The records of earthquakes which have been felt are confined to an imperfect list for Java, a few from the Mediterranean, and a few reported from the west coast of South America. Lastly, the hours, and in some cases even the days, on which cable-interruptions have taken place, together with the probable cause of these interruptions, are unknown. These latter facts are no doubt to be found in the archives of many cable companies, and it would be to the interest of all who desire to increase our knowledge of sub-oceanic change if comparisons could be made between the records of unfelt earthquakes now published, and the times and circumstances at and under which corresponding cable-ruptures have taken place.[1]

[1] The writer, whose address is Shide Hill House, Newport, I.W., England, would be glad to receive any information respecting the day, hour, and probable causes of failure, connected with cable-interruption.

All that it is expected to find is that a certain, and probably a small, proportion of these interruptions may correspond in time with seismic disturbances; and, because we know that certain cables have been lost by landslips and dislocations accompanying earthquake-movement, it is to be hoped that the expectation may be regarded as a reasonable conjecture.

An Attempt to estimate the Frequency of Submarine Dislocations.—If it can be assumed that the majority of cable-interruptions are due to submarine displacements, and not to faults inherent in themselves (which are comparatively of rare occurrence), the swaying of suspended sections under the influence of waves and currents, the movements of marine creatures, the boring of a *teredo*, and other exceptional causes, then the tables which have been given of cable fractures will give some idea of the frequency of such displacements. Because the list of interruptions for a number of the lines mentioned are imperfect, and because each cable follows a path carefully chosen as not being likely to suffer from submarine disturbance, the frequency of dislocation derived from such an assumption is more likely to be a minimum than a maximum. From the known number of interruptions which have occurred on sections of given length in a given number of years, the following table of dislocation frequency per mile of coast per year has been computed.

Cable Dislocation per Mile per Year.

Name of cable	Length in nautical miles	Number of breaks per mile per year
Mollendo—Chorillos	510	0·002
Arica—Mollendo	146	0·003
Iquique—Arica	128	0·0040
Antofagasta—Iquique	250	0·0000
Caldera—Antofagasta	229	0·0004
Coquimbo—Caldera	215	0·0000
Valparaiso—Coquimbo	219	0·001
Santos—Chuy	744	0·000
Maldonado—Montevideo	72	0·000
Chuy—Maldonado	125	0·000
Rio Grande do Sul—Chuy	148	0·000
Montevideo—Buenos Ayres	32	0·004
Sta. Catharina—Rio Grande do Sul	397	0·0004
Santos—Sta. Catharina	293	0·0005
Montevideo—Rio Grande do Sul	349	0·006
Chuy—Montevideo	201	0·001
Rio de Janeiro—Santos	223	0·009
Bahia—Rio de Janeiro	768	0·0011
Pernambuco—Bahia	404	0·0036
Ceara—Pernambuco	481	0·0018
Maranham—Ceara	408	0·004
Para—Maranham	381	0·008
St. Thomé—St. Paul de Loanda	785	0·003
Delagoa Bay—Durban	348	0·002
Mozambique—Delagoa	971	0·001
Zanzibar—Mombasa	150	0·007
Aden—Zanzibar	1,914	0·0008
	10,891	0·0023 average

The coasts taken are the east and west sides of South America and Africa. The total length considered representing shores which are steep and those which are gently inclined is about 11,000 miles. The general result which is reached is that the dislocations per mile per year, on the coast-lines considered, which may be taken as having on the average a character similar to that of the coast-lines of the world, are represented by the number 0·0023, that is to say, there is on the average one dislocation for every 434 miles per year. If we increase this number to 500 miles, and remember the character of the records and that of the paths to which they refer, although we have attributed *all* the interruptions to submarine change, we are inclined to the opinion that the estimate is not too great. This being granted, then, as there are about 156,000 miles of coast-line in the world, if the same were surrounded by loops of cables, although each section might be laid in the most favourable position, more than three hundred interruptions resulting from submarine disturbance might be expected to occur every year. In deep water on a level soft bottom experience shows that a cable may remain undisturbed and unchanged for long periods of time, indicating, as we have already pointed out, that geological change is proceeding with extreme slowness.

4. *Conclusions and Suggestions for a Seismic Survey of the World.*

Because earthquake origins are more numerous beneath the sea than upon the land, it is fair to assume that the bradyseismical operations resulting in the folding, bending, crushing, faulting, and thrusting of rock masses are more active in the recesses of the ocean than they are upon our continents. Sub-oceanic volcanic activity, as, for example, that which is met with in the mid-Atlantic, probably indicates the existence of bradyseismic movement and a relief of strain. The concentration of detritus derived from continental surfaces along coast-lines on tracts which are comparatively small, indicates that beneath the sea the growth by sedimentation is greater per unit area than the similarly estimated loss is by denudation on the land. This rapid submarine growth, largely under the influence of gravity, but modified by hydrodynamic action, leads to the building up of steep contours, the stability of which may be destroyed by the shaking of an earthquake, the escape of water from submarine springs, the change in direction or intensity of an ocean current, or by other causes which have been enumerated. That submarine landslides of great magnitude have had a real existence is proved for certain localities by the fact that after an interval of a few years very great differences in depth of water have been found at the same place, whilst sudden changes in depth have taken place at the time of and near to the origin of submarine earthquakes (see pp. 193 and 197). Large ocean-waves unaccompanied by volcanic action indicate that there have been very great and sudden displacements of materials beneath the ocean. The most important evidence of sub-oceanic change is, however, to be found amongst the archives of the cable engineer. The routes chosen for cables are carefully selected as being those where interruptions are least likely to occur; and yet, as it has been shown, something which is often of the nature of a submarine landslip takes place and some miles of cable may be buried. Here we seem to have proof positive, especially along the submerged continental plateaus, of sudden sub-oceanic dislocation. Because these changes are

frequent, it is reasonable to suppose that sedimentation and erosion and other causes which lead up to the critical conditions are geologically rapid.

Briefly, the foregoing notes and facts indicate that beneath the oceans certain important geological changes are more rapid than they are upon land, whilst new sources from which information respecting these changes may be obtained are pointed out to the student of dynamical geology.

The more important of these sources are the experiences of the cable engineer and the records of seismographs, which are sensitive to unfelt movements. When a number of these instruments have been established round the world, on the borders of great oceans, and on oceanic islands, it is difficult to overestimate the practical and scientific results which will follow.

The greater number of records, as it has been shown, would refer to disturbances which originated beneath the sea. From the times at which earth-waves arrived at different stations, as, for example, on the two sides of the Atlantic, it would be possible to localise their origins, and in time districts would be indicated which it would be well for those who lay cables to avoid. Work of this nature has, by means of ordinary seismographs, been *partially* accomplished for Japan, and the seismic maps of that country [1] show that sub-oceanic disturbances originating *near to the coast* are herded in groups. Should a trans-Pacific cable be landed in that country, to effect this through the middle of one of these groups would be inviting its destruction.

If we had the means of knowing that when an interruption occurred in a cable at the same time an unfelt earthquake had been recorded, we should then be in a position to attribute the fault to its proper cause. The practically simultaneous failure of three Atlantic cables in 1884 led to the hypothesis that they had been broken by the grapnels of a repairing vessel; fortunately for the owners of this vessel, it could not be substantiated.

From the 'Electrician' of August 20 and October 12, 1888, we learn that the simultaneous interruption of the two cables connecting Java and Australia in 1888 cut off the latter from the outside world for nineteen days, and gave a pretext for calling out the military and naval reserves to meet the contingency of war having broken out. In 1890 three cables were simultaneously broken, and telegraphic communication with Australia was cut off for nine days. On these occasions, had there been established in Australia a proper instrument for recording unfelt movements of the ground, it is extremely likely that the cause of the interruption would have been recognised as due to seismic action, and the fear of war and the probable accompanying commercial paralysis would have been averted. Other direct benefits, which have already been derived from the records of instruments such as it is here proposed to establish round the world, are that they enable us to extend, correct, and even to cast doubt upon certain classes of telegraphic information published in our newspapers.

Late in June last year we learned from our newspapers that a great disaster had taken place in North Japan, and that nearly 30,000 people had lost their lives. Seismograms taken in the Isle of Wight not only indicated how many maxima of motion had taken place, but showed that there had been an error in transmission of two days, the catastrophe

[1] See *Seismological Journal*, vol. iv.

having taken place on the evening of June 15, so that all who were to reach the stricken district after that date were in safety.

On August 31 of the same year, the Isle of Wight records showed that a disturbance similar to that which had occurred in Japan had taken place. On account of this similarity, it was stated that we should probably hear of a great earthquake having taken place in or near that country on the above date at 5.7 P.M. Four weeks later this was verified by mail. Another instance occurred some weeks later, when our newspapers announced that a great earthquake had taken place and several thousand lives had been lost in Kobe. No doubt those who had friends and property in that city were filled with anxiety. On this occasion the Isle of Wight instruments were still indicating that nothing of the magnitude described could have occurred. Later it was discovered that the telegram was devoid of all foundation.

If we next turn to the scientific aspect of the proposed investigations, we at once recognise the importance of the results which it is hoped may be obtained for the hydrographer and the student of physical geography and geology.

The greatest result which it is hoped may be achieved is to accurately determine the rate at which earthquake motion is propagated over long distances. In some instances the rates which have already been determined are so high, reaching 12 and more kilometres per second, that the supposition is, that motion does not simply go round our earth, but that it goes *through* the same; and if this is so, then a determination of these rates of transit will throw new light upon the effective rigidity of our planet.

Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Professor G. CAREY FOSTER (*Chairman*), Mr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Lord RAYLEIGH, Professors W. E. AYRTON, J. PERRY, W. G. ADAMS, *and* OLIVER J. LODGE, Drs. JOHN HOPKINSON *and* A. MUIRHEAD, Messrs. W. H. PREECE *and* HERBERT TAYLOR, Professors J. D. EVERETT *and* A. SCHUSTER, Dr. J. A. FLEMING, Professors G. F. FITZGERALD, G. CHRYSTAL, *and* J. J. THOMSON, Mr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Professor J. VIRIAMU JONES, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. G. FORBES, Mr. J. RENNIE, Mr. E. H. GRIFFITHS, *and* Professor A. W. RÜCKER.

AT the Liverpool meeting the Committee agreed that the 'calorie,' defined as the heat equivalent of $4{\cdot}2 \times 10^7$ ergs, should be adopted as the unit for the measurement of quantities of heat, but the question as to the exact part of the absolute thermodynamic scale of temperature at which

this quantity of heat could be taken as equal to one water-gramme-degree was for the time being left open.

This resolution has made it incumbent on the Committee to consider carefully—

1. The relation between the results of measurements of intervals of temperature by accepted methods and the absolute scale;
2. The specific heat of water in terms of the erg and its variation with temperature.

With regard to the first point there appears to be no reason to doubt that the scale of a constant-volume hydrogen-thermometer is very nearly identical with the absolute scale.[1] The Committee have therefore decided to recognise the standard hydrogen-thermometer of the Bureau International des Poids et Mesures as representing, nearly enough for present purposes, the absolute scale. This convention has at least the advantage of giving a definite meaning to statements of the numerical value of intervals of temperature within any range for which comparison with the hydrogen-thermometer is practicable. If future investigation should show that it is inaccurate to any appreciable extent, corresponding corrections can be applied when necessary.

Experience of the use of the platinum resistance-thermometer in various hands encourages the hope that it will afford a convenient and trustworthy working method of referring the indications of mercury- or other thermometers to those of the standard hydrogen-thermometer. The Committee have consequently much satisfaction in learning that Dr. C. A. Harker, formerly of Owens College, is at this moment carrying out at Sèvres, on behalf of the Committee of the Kew Observatory, and with the concurrence of the Director of the Laboratories of the Bureau International, a direct comparison of platinum thermometers belonging to the Kew Observatory with the standard hydrogen-thermometer of the Bureau.

As to the dynamical value of the specific heat of water—in other words the mechanical equivalent of heat—it was pointed out by Professor Schuster and Mr. Gannon in 1894[2] that the results of the best determinations by direct mechanical methods agree among themselves much more closely than they do with those that are founded upon electrical measurements of the energy expended, although these in turn are in good agreement among themselves. Additional significance is given to this remark by the comparison of those determinations which, by extending over an appreciable range of temperature, indicate the rate of variation of the specific heat of water. Of such determinations there is one of each kind, that of Professor Rowland by the mechanical method, and that of Mr. E. H. Griffiths by the electrical method. The results of the former of these have recently undergone an elaborate revision at the hands of one of Professor Rowland's pupils, Mr. W. S. Day,[3] who has compared the three principal thermometers employed in the experiments with the Sèvres hydrogen-standard by means of three Tonnelot thermometers which had been compared at the Bureau with the hydrogen-standard. Messrs. C. W. Waidner and F. Mallory[4] have also compared two of

[1] See Appendix No. 1 to this Report.

[2] *Phil. Trans.*, vol. clxxxvi., p. 462; *Proc. Roy. Soc.*, vol. lvii., p. 31.

[3] Johns Hopkins *University Circulars*, pp. 44, 45 (June 1897); also *Phil. Mag.*, xliv. 169–172.

[4] *Ibid.*, pp. 42, 43 (June 1897); *Phil. Mag.*, xliv. 165–169.

Rowland's thermometers with a platinum thermometer made by Mr. Griffiths. The result of this discussion is to leave Rowland's original value unchanged at 15°, and to raise it by four parts in 4,000 at 25°, making the rate of variation of the specific heat of water almost exactly the same as that given by Griffiths's experiments throughout the same range.

The following table gives the numerical values :—

Values of the Specific Heat of Water at 15° *C.*

1. By mechanical friction :—

Author	Date	Result
Joule	1878	4172×10^4 ergs.
Miculescu	1892	4181 „
Rowland	1879	4189 „
Reynolds and Moorby . .	1897	4183×10^4 { mean specific heat from 0° to 100° C.

2. By electrical methods :—

Author	Date	Result
Griffiths	1893	$4199{\cdot}7 \times 10^4$ ergs.
Schuster and Gannon . .	1894	4197 „

Variation of the Specific Heat of Water.

Temperature	Specific Heat	
	Rowland	Griffiths
6	4204×10^4	—
10	4197 „	—
15	4189 „	$4199{\cdot}7 \times 10$
20	4183 „	4193·2 „
25	4177 „	4187·4
30	4173 „	—
35	4174 „	—

Joule's (1878) result is given by Schuster and Gannon (*Proc. Roy. Soc.*, lvii. p. 31) as 775 foot-pounds at Greenwich per degree Fahr. As Professor Schuster has examined the thermometers employed by Joule, this value is adopted as the most trustworthy statement of the result of Joule's experiments : it is reduced to ergs and the Centigrade scale.

Miculescu (*Ann. Chim. Phys.* [6], xxvii. 237) states his result as 426·84 kilogramme-metres per kilogramme-degree of the normal hydrogen-thermometer between 10° and 13°. Taking $g = 980{\cdot}96$, this is equivalent to 4187×10 ergs per gramme-degree. The mean temperature 11°·5 has been adopted and reduction to 15° has been made by means of the rate of variation given by Rowland's experiments.

Reynolds' and Moorby's experiments (*Proc. Roy. Soc.*, lxi.) refer to the whole range from 0° to 100°. Their result is stated, in foot-pounds at Manchester and degrees Fahr., as 776·94. To reduce to ergs and the Centigrade scale this number has been multiplied by $1{\cdot}8 \times 30{\cdot}48 \times 981{\cdot}34$.

Schuster and Gannon (*Proc. Roy. Soc.*, lvii. 25–31).

Rowland's and Griffiths' results are quoted from Day (*Phil. Mag.*, August 1897, p. 171), whose statement is adopted by Griffiths in *Nature* for July 15, 1897.

The agreement between the separate determinations by the mechanical and by the electrical methods respectively, and the regularity of the differences between Rowland's values and those of Griffiths, is such as to raise a strong presumption that, in the experiments by both methods, errors of observation have been reduced to a very small amount. At the same time the difference between the two sets of results points to some constant source of error in the measurement of energy affecting one or both. The mechanical method is, in principle, so direct and simple that it is difficult to suppose its results affected by a constant error. On the other hand, the electrical method being less direct and more complicated, there is here more room for uncertainty in the data.

The electrical determinations depend upon the well-known relation between thermal and electrical energy, which is expressible in the three forms—

$$JH = C^2Rt = CEt = \frac{E^2}{R}t.$$

Schuster and Gannon's experiments are based upon the second form of the equation, those of Griffiths on the third. In both of them electromotive force was measured by comparison with a Latimer Clark's cell. Schuster and Gannon measured, in addition, the strength of their current by means of a silver-voltameter, and Griffiths measured a resistance in terms of the ohm.

The accepted value of the electromotive force of the Clark's cell depends in its turn on the electrochemical equivalent of silver as determined by Lord Rayleigh and Professor F. Kohlrausch, and consequently it appears that the electrical determinations of the mechanical equivalent involve a double reference to the electrochemical equivalent of silver, so that any inaccuracy in the adopted value of this quantity would involve a duplicate error in the value of the mechanical equivalent deduced therefrom.

In this connection it may be mentioned that, in a recent letter to 'Nature,' vol. lvi. p. 292, Lord Rayleigh has stated that he does not consider that a possible error of one part in 1,000 is excluded from his determination of the electrochemical equivalent of silver. If it be assumed that his value is one part in 1,000 too small, this would almost exactly account for the difference between the electrical determinations into which this quantity enters as a factor and the direct mechanical determinations.

It thus appears to be a matter of urgent importance that a redetermination of the electrochemical equivalent of silver should be made, and that the general question of the absolute measurement of electric currents should be investigated. In order to enable them to carry out this investigation, the Committee have decided to ask for reappointment and to apply for a grant of 100*l.* towards the expense of the necessary apparatus and experiments.

APPENDIX I.

Note on the Constant-volume Gas-thermometer.
By G. CAREY FOSTER, *F.R.S.*

The absolute thermodynamic scale of temperature introduced by Lord Kelvin is connected with the properties of real fluids by the equation [1]

$$\frac{d\mathrm{T}}{\mathrm{T}}=\frac{dv}{v+\frac{\delta w}{\delta p}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where dv is the infinitesimal increment which unit mass of a fluid occupying the volume v undergoes when it is heated, under constant pressure, from the absolute temperature T to the infinitesimally higher absolute temperature $\mathrm{T}+d\mathrm{T}$, and δw is the amount of work required to restore the original temperature of unit mass of the fluid when it has undergone a fall of pressure, δp, by passing through a porous plug, as in Joule and Thomson's experiments, without loss or gain of heat.

It follows that, if there is any fluid which does not undergo a change of temperature when forced through a porous plug, an infinitesimal change of temperature is to the total temperature on the absolute scale as the resulting change of volume of this fluid is to the total volume. Such a fluid would be called a perfect gas.

The following discussion of the bearing of the results of the porous-plug experiments on the indications of a constant-volume gas-thermometer is taken from a copy which the writer made in January 1894 of a fuller discussion of these experiments communicated to him by his friend and former pupil, Mr. John Rose-Innes. Mr. Rose-Innes will shortly read a paper on this question before the Physical Society of London. In the meantime the writer has his permission to make the present use of his hitherto unpublished results.

It will be remembered that Joule and Lord Kelvin found that all the gases they experimented on were, with the exception of hydrogen, slightly cooled by being forced through the plug. With hydrogen the effect was smaller than with other gases and was a rise of temperature. At a given temperature the cooling effect was, up to five or six atmospheres, proportional to the difference of pressure on opposite sides of the plug. For a given change of pressure the effect decreased with rise of temperature, and Joule and Lord Kelvin concluded that it was approximately proportional to the inverse square of the temperature reckoned from $-273°$ C. With hydrogen the variation with temperature was too small for them to consider it as clearly established; if anything the effect became greater as the temperature rose.

Mr. Rose-Innes's discussion of these results is founded upon his remark that an empirical formula with two constants, α and β, namely

$$\theta=\frac{\alpha}{273+t}+\beta,$$

[1] Compare equation (16) of Lord Kelvin's article 'Heat' in the *Encyclopædia Britannica*, vol. xi. p. 571; *Mathematical and Physical Papers*, vol. iii.

where θ is the cooling effect and t temperature on the ordinary centigrade scale, represents the experimental values rather more accurately than the inverse-square formula. The values of α and β calculated by him for air, carbonic acid gas, and hydrogen, the change of pressure being represented by 100 inches of mercury, are as follows :—

	α	β
Air . . .	441·5	−0·697
Carbonic Acid . .	261·5	−4·98
Hydrogen . . .	64·1	− ·331

To apply equation (1) to the discussion of the gas-thermometer, we may begin (like Joule and Kelvin) by expressing the work δw, required to restore the gas to its initial condition, in terms of the observed cooling effect, and may write

$$\delta w = \mathrm{JC}\theta = \mathrm{JC}\left(\frac{\alpha}{\mathrm{T}} + \beta\right),$$

where J is the mechanical equivalent of heat and C the specific heat of the gas under constant pressure. If we remember that J may be written $\mathrm{J}=\mathrm{W}/m\theta'$, where W is the work that must be spent to raise the temperature of a mass m of water by the amount θ', we see that the thermometric scale on which θ and θ' are expressed is of no consequence, provided it is the same for both.

Putting Π for the change of pressure producing a cooling effect θ, we may write equation (1) thus, taking reciprocals of both sides :

$$\mathrm{T}\frac{dv}{d\mathrm{T}} - v = \frac{\mathrm{JC}}{\Pi}\left(\frac{\alpha}{\mathrm{T}} + \beta\right) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

or, dividing throughout by T^2 and integrating between limits T and infinity—

$$\left(\frac{v}{\mathrm{T}}\right)_{\infty} - \frac{v}{\mathrm{T}} = \frac{\mathrm{JC}}{\Pi}\left(\frac{\alpha}{2\mathrm{T}^2} + \frac{\beta}{\mathrm{T}}\right) \quad . \quad . \quad . \quad . \quad (3)$$

With regard to the first term on the right, it may be remarked that all gases appear to approximate more and more nearly as temperature rises to agreement with the equation $\frac{pv}{\mathrm{T}}=\mathrm{R}$ (a constant). Applying this to (3), we get

$$\frac{\mathrm{R}}{p} - \frac{v}{\mathrm{T}} = \frac{\mathrm{JC}}{\Pi}\left(\frac{\alpha}{2\mathrm{T}^2} + \frac{\beta}{\mathrm{T}}\right),$$

or,

$$p = \frac{\mathrm{RT}}{v} - \frac{\mathrm{JC}}{\Pi}\cdot\frac{p}{v}\left(\frac{\alpha}{2\mathrm{T}} + \beta\right) \quad . \quad . \quad . \quad . \quad (4)$$

Neglecting, provisionally, the Joule-Kelvin effect, we have, as a first approximation,

$$p = \frac{\mathrm{RT}}{v};$$

and we may take this value as accurate enough for use in the small term containing p on the right-hand side of (4).

We thus get, as a second approximation to the value of p—

$$p=\frac{R}{v}\left[T-\frac{JC}{\Pi v}(\tfrac{1}{2}a+\beta T)\right] \quad . \quad . \quad . \quad (5)$$

Now let v remain constant, and let p_0, T_0 and p_1, T_1 represent pressure and temperature at the melting-point of ice and at the boiling-point of water respectively ; we then get

$$p_0=\frac{R}{v}\left[T_0-\frac{JC}{\Pi v}(\tfrac{1}{2}a+\beta T_0)\right]$$

$$p_1=\frac{R}{v}\left[T_1-\frac{JC}{\Pi v}(\tfrac{1}{2}a+\beta T_1)\right].$$

By subtraction

$$p-p_0=\left(\frac{R}{v}-\frac{RJC\beta}{v^2\Pi}\right)(T-T_0),$$

and

$$p_1-p_0=\left(\frac{R}{v}-\frac{RJC\beta}{v^2\Pi}\right)(T_1-T_0).$$

Hence

$$\frac{p-p_0}{p_1-p_0}=\frac{T-T_0}{T_1-T_0},$$

or, finally, if we assume 100 as the numerical value of the interval T_1-T_0

$$T-T_0=100\,\frac{p-p_0}{p_1-p_0};$$

whence we may conclude that, to the degree of approximation attained in this calculation, the scale of the constant volume gas-thermometer is identical with the absolute thermodynamic scale.

APPENDIX II.

On a Determination of the Ohm made in Testing the Lorenz Apparatus of the McGill University, Montreal, by Professor W. E. Ayrton, *F.R.S., and* Professor J. Viriamu Jones, *F.R.S.*

This apparatus, made by Messrs. Nalder Brothers, is in general arrangement and dimensions similar to the Cardiff apparatus described in the 'Philosophical Transactions of the Royal Society,' 1891, A, pp. 1–42, and in the 'Electrician,' June 1895, vol. xxxv. pp. 231 and 253.

The field coil, in pursuance of a suggestion contained in the Royal Society paper, consists of a single layer of wire wound in a helical groove of semicircular section, cut in the cylindrical surface of a massive marble ring of about 21 inches outside diameter, 15 inches inside diameter, and 6 inches thick. This helical groove has 201 complete turns with a pitch of 0·025 inch. Bare wire, of mean thickness 0·02136 inch, was first used,

and the outside diameter of the coil so wound was measured in the Whitworth machine with the following results :—

Diameter	Near front face	Near middle	Near back face
0° – 180°	21·04772	21·04765	21·04765
10° – 190°	21·04795	21·04765	21·04952
20° – 200°	21·04768	21·04755	21·04905
30° – 210°	21·04805	21·04745	21·04818
40° – 220°	21·04785	21·04755	21·04825
50° – 230°	21·04808	21 04730	21·04812
60° – 240°	21·04752	21·04755	21·04805
70° – 250°	21·04755	21·04755	21·04822
80° – 260°	21·04785	21·04795	21·04895
90° – 270°	21·04812	21·04780	21·04942
100° – 280°	21·04805	21·04815	21·04925
110° – 290°	21·04808	21·04825	21·04898
120° – 300°	21·04785	21·04840	21·04905
130° – 310°	21·04828	21·04835	21·04915
140° – 320°	21·04828	21·04815	21·04908
150° – 330°	21·04805	21·04805	21·04932
160° – 340°	21·04872	21·04795	21·04858
170° – 350°	21·04778	21·04785	21·04812
	Mean 21·04797	21·04784	21·04872

General mean = 21·04818 inches.

The temperature, which was taken at each observation, varied between 19°·9 C. and 21° C., and had a mean value of 20°·4 C. Correcting for the difference between the temperature at which the bars of the Whitworth machine have their specified value and this mean temperature, we have for the mean outside diameter of the coil, when wound with bare wire 0·02136 inch thick,

21·04932 inch at 20°·4 C.

From the above measurements it is clear that the wire lay on a very true circular cylinder. With bare wire, however, of the thickness used it was found impossible to obtain sufficient insulation between pairs of convolutions. Hence, after much time had been spent in endeavouring to insulate the successive turns by forcing paraffin wax in between them, &c., the coil was unwound and rewound with double silk covered wire which had been first dried, then drawn through paraffin wax, and lastly baked before the winding was commenced. To wind so large and heavy a ring was not an easy matter, and it was not until the winding had been performed three times that the layer looked sufficiently uniform and quite free from abrasion of the silk.

The mean thickness of the double silk covered wire used in the last winding was 0·01914 inch, so that the outside diameter of the wound coil, calculated from the value given above for the coil wound with bare wire, was

21·04488 inches at 20°·4 C.

The coil was then brushed over with melted paraffin wax, bound round with silk ribbon that had been soaked in a solution of shellac, and finally loosely covered up with a wide silk ribbon that had been passed through paraffin wax.

During the time that the ring was unwound the linear coefficient of expansion of the marble was measured by Messrs. Spiers, Twyman, and Waters, three of the students of the City and Guilds Central Technical College. The experiment was attended with difficulty, for it was far from easy to bring so large a mass of a badly conducting substance to the same temperature, but ultimately the result 0·000004 per 1° C. was obtained.

At the conclusion of the resistance observations recorded further on, the silk ribbons and the protecting layer of paraffin wax were carefully removed until the silk covering of the wire appeared, and the diameter of the coil was measured along two directions at right angles to one another. The maximum difference between four measurements was only five hundred-thousandths of an inch, and after the introduction of the proper temperature corrections, the mean value of the outside diameter of the coil was found to be

21·04687 inches at 20°·4 C.

This result is about one part in ten thousand larger than the calculated value given above, and the difference is probably due to the silk covering of the wire having swollen slightly when the wound coil was brushed over with melted paraffin wax. In the calculation, therefore, of the coefficient of mutual induction we have considered it more accurate to use the value obtained by direct experiment. Subtracting from that value—21·04687—the thickness of the double silk-covered wire—0·01914—we have for the mean diameter of the coil *from axis to axis of the wire*

21·02773 inches at 20°·4 C.

Shortly before the last set of resistance measurements was carried out, the edge of the phosphor bronze disc was ground in position so as to be made quite true with the axis of rotation, and immediately after the completion of the investigation the diameter of the disc was measured and found to be 13·01435 inches at 19°·5 C. Messrs. Spiers, Twyman, and Waters had previously determined its linear coefficient of expansion to be 0·0000125 per 1° C., so that its diameter was

13·01451 inches at 20°·4 C.

During 1896 Mr. W. G. Rhodes, when he was an Assistant at the Central Technical College, carried out the long calculation of the coefficient of mutual induction between the coil, as wound with bare wire, and the disc by using the method given in the paper in the 'Philosophical Transactions' above referred to, and with the following values:—

Diameter of coil or 2 A $=21·02673$ inches.
Diameter of disc or $2\,a$ $=13·01997$ inches.
Axial length of helix or $2\,x$ $=5·025$ inches.
Number of convolutions or $n=201$

He found

$$\text{M}=18056·36 \text{ inches.}$$
$$=45862·33 \text{ centimetres.}$$

This calculation was checked by Mr. Mather and independently by one of the authors.

Now it can be shown that for the above values of A, a, x, and n

$$\frac{d\text{M}}{\text{M}}=1·246\,\frac{d\text{A}}{\text{A}}+2·346\,\frac{da}{a}+0·0997\,\frac{dx}{x},$$

and so the value of M for the particular values of 2 A and $2a$ given above, viz. 21·02772 and 13·01451 can be calculated. When this is done we find

$$M = 18037{\cdot}51 \text{ inches.}$$
$$= 45814{\cdot}45 \text{ centimetres.}$$

and this was the value of M which we employed in our final determination, after allowance had been made for the effect of the central brush, as will be described further on.

The accuracy of the preceding calculations was tested in the following way. Values of 2 A and $2a$, differing slightly from those employed by Mr. Rhodes, were selected, and by means of the formula for $\frac{dM}{M}$ the proportional change in M was determined by Mr. Twyman. Then the value of M for these changed values of 2 A and $2a$, was calculated by the authors from a new formula involving an elliptic integral of the third kind.[1]

The centre brush consists of a tube, 0·135 inch outside diameter, which projects into an axial hole in the disc of 0·144 inch diameter. Contact with the edge of the disc is made by three small tangential phosphor bronze tubes lightly pressed on it, at points separated by angular distances of 120°. Through all four tubes a small stream of mercury is kept flowing, as this is found to greatly diminish the disturbances caused by variations in the thermo-electric effects; and the employment of three brushes at the circumference, as suggested by Rowland, eliminates small errors due to imperfect centering of the coil and disc.

To prevent the mercury which drops out of the central tube-brush touching the disc at a larger radius than that of the hole in its centre an ebonite boss is cemented to the disc, and this causes the mercury to drop away quite clear of the metal of the disc.

If we take as the effective outside diameter of the central tube 0·139 inch, that is the mean of 0·135 and 0·144 inch, calculation shows that tho coefficient of mutual induction is reduced by 4·50 centimetres, so that finally we have

$$M = 45809{\cdot}95 \text{ centimetres.}$$

As the allowance for the central brush only diminishes M by one part in ten thousand it is clear that, for that degree of accuracy, an error of a few per cent. in estimating the diameter of the central brush is of no consequence.

The method of making the observations was the same as that described in the papers on the Cardiff apparatus read before Section A of the British Association at Nottingham and Oxford (*vide* Report of the Committee on Electrical Standards, Appendices 1893 and 1894). The use of an extremely sensitive Ayrton-Mather galvanometer of the d'Arsonval type materially facilitated the readings being taken. Two such narrow coil galvanometers were specially constructed by Mr. Mather himself for use

[1] An account of this new formula as well as of that for $\frac{dM}{M}$ will shortly be published by Professor Viriamu Jones.

with the Lorenz apparatus, and the data of the second instrument are contained in the following table.

Resistance of suspended coil	1·9 ohms.
" coil and suspension . . .	5·75 "
Periodic time of complete swing . . .	7·6 seconds.
Scale distance actually used . . .	1412 millimetres. 1340 scale divisions.
Deflection in divisions at actual scale distance used	137 per micro-ampere. 23·8 " micro-volt.
Deflection in divisions at scale distance equal to 2,000 scale divisions	204 " micro-ampere. 35·8 " micro-volt.

The resistance coils used were those previously employed in the Cardiff determination of the ohm (*vide* Report of the Committee on Electrical Standards, Appendices II. and III., 1894). They have been tested once by Mr. Glazebrook, and twice by the kindness of Major Cardew in the Board of Trade Electric Standardising Laboratory, with the following results :—

Coil.	A. Mr. Glazebrook, Jan.-March 1894.	B. Board of Trade, November 1896.	C. Board of Trade, August 1897.
No. 3,873	9·9919 at 14°·8 C.	9·992994 at 14°·86 C.	10·00712 at 19°·3 C.
" 3,874	9·9926 at 14°·9 C	9·993213 at 14°·91 C.	10·00775 at 19°·3 C.
" 4,274	·100050 at 15°·2 C.	·1000595 at 14°·77 C.	·100078 at 19°·4 C.
" 4,275	·100053 at 15°·2 C.	·1000722 at 15°·14 C.	·100081 at 19°·4 C.

The coils Nos. 3,873 and 3,874 were stated by the makers, Messrs. Nalder, to be wound with platinum silver wire, and the two others, Nos. 4,274 and 4,275, with manganin.

In the following table are given the temperature coefficients as supplied originally by the makers, and as calculated from the tests A and C, and B and C.

Temperature Coefficients of Resistance per 1° *C.*

Coil.	As supplied by Messrs. Nalder.	From tests A and C.	From tests B and C.
No. 3,873	0·000276	0·000360	0·000318
" 3,874	0·000300	0·000344	0·000331
" 4,274	0·0000127	0·0000667	0·0000399
" 4,275	0·0000127	0·0000667	0·0000207

These figures show that a redetermination of the temperature coefficients, which we are now carrying out, is necessary.

Fortunately the last set of determinations of the resistance of these four coils was carried out at Westminster, within a fortnight of the completion of our absolute measurements, and we are much indebted to Major Cardew for his kind promptness in the matter. The temperatures of these 1897 Board of Trade measurements were so nearly those of the coils during our final absolute determinations, which were from 18°·8 to 19°·4 C., as

to render the effect of possible errors in the temperature coefficients negligible to the degree of accuracy aimed at by us. We have, therefore, used the August 1897 Board of Trade values for these coils as transmitting the Board of Trade ohm to the laboratory in Exhibition Road.

The standard thermometers used in the investigation were sent to Kew and their errors were determined at the time by the kindness of Dr. Chree; also, thanks to Sir J. Norman Lockyer, the clock in the Mechanical Department of the Central Technical College, which transmitted seconds to the fast running Bain Chronograph, was frequently timed by reference to the current sent hourly to his room from the General Post Office, and at 10 A.M. from Greenwich.

The results of successive measurements of the absolute resistances became very concordant after, little by little, various possible causes of small errors had been eliminated. Nine sets taken on July 30, 1897, gave the following results for the value of the Board of Trade ohm in true ohms, without allowance for the error in the clock rate.

1·000286	1·000277
1·000256	1·000306
1·000285	1·000284
1·000351	1·000307
1·000295	

Mean 1·000294

or, since the clock was found to lose, during the daytime, at the rate of three seconds per twenty-four hours, it follows that according to this investigation

1 Board of Trade ohm = 1·00026 true ohms.

It is important to consider in which direction this result will be affected by sources of error that cannot be removed by careful adjustment, centering, &c. They may be classified as follows :—

Source of Error.	Effect Produced.
1. Over-estimation of the diameter of the coil arising, for example, from the stress on the copper wire having caused it to compress the under side of its silk covering.	Result would be too small.
2. Under-estimation of the diameter of the phosphor bronze disc from a neglect of the tips of the circumferential brush tubes being possibly pushed away from the disc by the stream of mercury issuing, &c.	Result would be too small.
3. Presence of iron pipes, girders, &c. in the neighbourhood of the apparatus.	Result would be too small.
4. Traces of iron in the phosphor bronze disc.	Result would be very slightly too small.
5. Defective insulation between the support of the central brush and the supports of the circumferential brushes.	Result would be too large.
6. Defective insulation between the convolutions on the coil.	Result would be too large.
7. Traces of iron in the marble ring.	Result would be too large.

8. Defective insulation of parts of the circuit from one another.	Effect would depend upon the position of the leaks.
9. Permanent magnetic field at the apparatus.	No effect, for the current through the field coil was periodically reversed.

As regards 4 and 7, special induction balances were constructed and used by Mr. Mather to test the permeability of both the marble ring and the phosphor bronze disc; but, although a deviation from unity of one part in fifteen thousand could have been detected in the permeability of either, no such deviation was observed.

As regards 5 and 8, careful tests were made every day of the insulation resistance of the apparatus, and it was always found to be greater than one thousand megohms.

6. The insulation between the adjacent convolutions of wire could not be measured when they were silk covered and buried in paraffin wax, since a small leak between a pair of turns would not change the apparent resistance of the copper coil by as much as the variation in temperature of a fraction of one degree. We had, therefore, to content ourselves with the precautions, previously described, which were taken to secure high insulation in the winding of the coil.

When the ring was wound with bare wire it was possible to roughly compare the insulation resistance between pairs of convolutions by sending a constant current through the coil and measuring, very accurately, the P.D. between every adjacent pair of the 201 turns. This we did several times, but it was a long and laborious task.

When constructing a new Lorenz apparatus it will be well to consider whether two separate helices should not be cut in the cylindrical surface of the marble ring in which two independent bare wires would be bound, a turn of the one being everywhere (except at the extreme ends) between two turns of the other. The insulation resistance, therefore, between the two windings would measure the insulation between the adjacent turns, while in the ordinary use of the apparatus the two windings would be joined in series so as to constitute a single coil. In this way it may be possible to be more sure of the absence of 6 than by using paraffined double silk covered wire, and at the same time, to entirely remove 1.

The *direction* of our experimental result, which shows that the Board of Trade ohm is between two and three parts in ten thousand *larger* than the true ohm could not, however, arise from 1. Nor could it arise from either 2 or 3, still many experiments were made to detect any evidence of the effective diameter of the disc being larger than its true diameter, as measured in the Whitworth machine. But no change in the pressure of the circumferential brush-tubes, nor alteration in the shape of their ends, &c., indicated that, with the brushes as we employed them, the effective diameter of the disc differed from its true diameter.

Our thanks are due to the three students whose names are given above for much assistance in carrying out the long series of observations; to Mr. Harrison for bringing to bear, from time to time, the experience that he had previously gained in the use of the Lorenz apparatus; and we are especially indebted to Mr. Mather for the suggestive aid which he rendered us throughout the whole of the present investigation.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLaren, Professor A. Crum Brown (*Secretary*), Dr. John Murray, Dr. Alexander Buchan, *and* Professor R. Copeland. (*Drawn up by* Dr. Buchan.)

The Committee was appointed, as in former years, for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories.

The hourly eye observations by night as well as by day have been made with the utmost regularity by Mr. Angus Rankin, the Acting Superintendent, and the assistants during the year. The continuous registrations and other observations have been carried on at the Low Level Observatory at Fort William with the same accuracy and fulness of detail as heretofore.

The Directors of the Observatories tender their best thanks to Messrs. A. J. Herbertson, T. S. Muir, A. Drysdale, M.A., B.Sc., P. S. Hardie, George Ednie, and John S. Begg, for the invaluable assistance rendered by them as volunteer observers during the summer and autumn months, thus giving much needed relief to the members of the regular observing staff.

Table I. shows for the year 1896 the mean monthly and extreme pressures and temperatures; amounts of rainfall, with the days of rain, and the number of days when the amount exceeded one inch; the hours of sunshine; the mean percentage of cloud; the mean velocity of the wind in miles per hour at the top of the mountain; and the mean rainband at both observatories. The mean barometric pressures at Fort William Observatory are reduced to 32° and sea level, but those at the Ben Nevis Observatory are reduced to 32° only.

Table I.

1896	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·534	25·507	25·021	25·443	25·711	25·410	25·459	25·460	25·172	25·127	25·488	25·077	25·367
Fort William	30·179	30·140	29·597	30·045	30·266	29·890	29·958	29·974	29·646	29·704	30·092	29·661	29·929
Differences	4·645	4·632	4·576	4·602	4·555	4·480	4·499	4·514	4·474	4·577	4·604	4·584	4·562
Mean Temperatures.													
Ben Nevis Observatory	28°·2	28°·1	25°·2	29°·4	38°·9	41°·1	40°·5	38°·6	37°·0	26°·7	29°·9	25°·2	32°·4
Fort William	41·3	43·4	41·5	46·7	53·8	56·2	56·7	55·4	53·1	42·6	43·3	39·1	47·8
Differences	13·1	15·3	16·3	17·3	14·9	15·1	16·2	16·8	16·1	15·9	13·4	13·9	15·4
Extremes of Temperature, Maxima.													
Ben Nevis Observatory	42°·0	38°·9	37°·2	44°·8	53°·2	61°·3	52°·9	50°·0	48°·7	43°·0	39°·8	39°·1	61°·3
Fort William	55·0	52·0	52·1	60·6	75·2	78·6	70·3	67·0	67·4	57·3	52·2	51·7	78·6
Differences	13·0	13·1	14·9	15·8	22·0	17·3	17·4	17·0	18·7	14·3	12·4	12·6	17·3
Extremes of Temperature, Minima.													
Ben Nevis Observatory	14°·2	16°·8	15°·5	19°·4	20°·2	30°·9	31°·3	29°·9	27°·3	14°·4	16°·0	14°·8	14°·2
Fort William	25·5	33·6	27·6	30·2	34·7	46·3	42·4	40·0	35·4	25·9	24·7	22·6	22·6
Differences	11·3	16·8	12·1	10·8	14·5	15·4	11·1	10·1	8·1	11·5	8·7	7·8	8·4

TABLE I.—*continued.*

1896	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Rainfall in Inches.							
Ben Nevis Observatory	16·20	11·15	19·55	10·04	2·91	9·74	6·87	11·01	10·78	13·07	9·77	12·47	133·56
Fort William	9·50	8·26	10·64	3·65	1·27	5·05	3·96	6·29	7·01	5·55	4·68	8·63	74·49
Differences	6·70	2·89	8·91	6·39	1·64	4·69	2·91	4·72	3·77	7·52	5·09	3·84	59·07
						Number of Days 1 *in. or more fell.*							
Ben Nevis Observatory	5	4	7	3	1	3	2	3	3	5	3	5	44
Fort William	3	3	2	0	0	0	0	2	1	1	0	4	16
Differences	2	1	5	3	1	3	2	1	2	4	3	1	28
						Number of Days of Rain.							
Ben Nevis Observatory	23	17	26	26	12	20	21	24	22	26	18	24	259
Fort William	24	18	24	22	7	20	18	21	21	21	17	24	237
Differences	−1	−1	2	4	5	0	3	3	1	5	1	0	22
						Mean Rainband (*scale* 0–8).							
Ben Nevis Observatory	1·9	2·4	2·7	1·8	1·9	2·4	3·3	2·8	2·7	2·0	1·6	1·7	2·3
Fort William	3·6	3·8	3·9	3·5	3·8	4·4	4·6	4·5	5·4	3·4	3·5	3·5	4·0
Differences	1·7	1·4	1·2	1·7	1·9	2·0	1·3	1·7	2·7	1·4	1·9	1·8	1·7
						Number of Hours of Bright Sunshine.							
Ben Nevis Observatory	36	33	30	33	222	79	90	81	29	41	59	23	756
Fort William	17	28	85	93	231	129	135	131	74	71	25	17	1,036
Differences	−19	−5	55	60	9	50	45	50	45	30	−34	−6	280
						Mean Hourly Velocity of Wind in Miles.							
Ben Nevis Observatory	14	12	13	11	13	6	11	9	13	16	13	18	12
						Mean Percentage of Cloud.							
Ben Nevis Observatory	80	86	92	92	56	89	86	87	91	84	70	86	83
Fort William	82	87	77	80	54	78	83	80	80	70	74	76	77
Differences	−2	−1	15	12	2	11	3	7	11	14	−4	10	6

At Fort William the mean atmospheric pressure for the year, at 32° and sea level, was 29·929 inches, and at the top reduced only to 32°, 25·367 inches, being respectively 0·082 inch and 0·071 inch above the averages. The difference for the two Observatories was thus 4·562 inches, being only very slightly more than the average difference. At the top of the mountain the absolute maximum pressure for the year was 26·252 inches, occurring at 10 A.M. of January 9, which is the highest yet observed since the Observatory was established in 1883. At Fort William at the same hour the pressure was 30·102 inches, also the highest hitherto noted there.

The barometric observations at this time will be long remembered as having been in all parts of the British Islands absolutely the highest hitherto recorded in each locality since barometers began to be in use. In the morning of January 9, a broad belt of low temperature stretched across Scotland from the Lewis to the Lothians, and it was within this low temperature area that the absolutely highest readings of the barometer were made. At several stations in the counties of Stirling, Dumbarton, and the west of Perthshire, the sea-level readings rose to or slightly exceeded 31·100 inches, the absolute highest of all being 31·108 inches at Ochtertyre. It is remarkable that it was at Ochtertyre that the lowest

barometric observation hitherto made occurred, that observation being 27·333 inches, thus giving the range of 3·775 inches, a range which future observation is not likely to increase. The weather at the time was strongly anticyclonic, as the subjoined extracts from the Observatories show :—

TABLE II.

	Top of Ben Nevis.	Fort William.
	°	°
Dry bulb	29·0	26·7
Wet ditto	21·3	26·4
Cloud	0	10
Wind	ENE2	
Sunshine, 9 to 10	60 min.	none

The differences from the mean monthly pressures greatly exceeded the average in January, February, May, July, August, and November, those for January and May being greater than any that had occurred for the previous forty years, and in these months accordingly relatively high temperatures ruled on the top of Ben Nevis.

The following Table shows the deviations from the mean temperatures of the months from the respective averages :—

TABLE III.

	Fort William.	Top of Ben Nevis.
	°	°
January	2·6	4·4
February	4·1	4·2
March	1·4	1.4
April	1·3	1·9
May	4·1	5·6
June	1·1	2·1
July	−0·2	0·2
August	−0·9	−1·2
September	0·4	−0·9
October	−4·1	−4·3
November	−0·4	1·9
December	−0·5	0·2
Year	0·9	1·0

Thus it is seen the temperature at the top of Ben Nevis was relatively much higher than at Fort William in January, May, and November, when well developed anticyclones were of most frequent occurrence.

During the first half of the year temperature was above the average at both Observatories, the mean excess at Fort William being 2°·4 and at the top of Ben Nevis 3°·3. On the other hand, during the second half of the year the mean temperature was 1°·0 under the normal at Fort William, and 0°·8 at the top of Ben Nevis. The two extreme months were February, when mean temperature was fully 4°·0 above the normal, and October, when it was fully 4°·0 under it at the two Observatories.

The absolutely highest temperature recorded during the year was 79°·9, on June 14 at Fort William, and 61°3, also on June 14, at the top of Ben Nevis. The absolutely lowest temperature was 22°·0 on December 18 at Fort William, and at the top 14°·2 on January 23. The minimum temperatures are exceptionally high for both places. At the top of the

mountain 14°·2 is the highest minimum temperature of any year since the Observatory was established.

As regards extremes of temperature the difference between the two maxima was greatest in May, when it was 22°·0, and least in December, when it was 12°·6 ; and the difference between the two minima was greatest in February, when it was 16°·8, and least in December, when it was only 7°·8.

The registrations of the sunshine recorder at the top show 756 hours out of a possible 4,470 hours, being 61 hours more than in 1895. This equals 17 per cent of the possible sunshine. The maximum was 222 hours in May, being the highest hitherto recorded in any month except in June 1888, when the number of hours of clear sunshine was 250. The minimum was 23 hours in December, no higher monthly minimum having yet been recorded in any year. At Fort William the number of hours for the year was 1,036, being 96 hours fewer than in 1895. This great difference in favour of the top was due to a greater prevalence of anticyclones during 1896, when clearer weather prevails at the top than at the foot of the mountain. The maximum was 231 hours in May and the minimum 17 in January and again in December. As the number of hours of possible sunshine at Fort William is 3,497, the sunshine of 1896 was 30 per cent. under the possible.

In the subjoined Table are given for each month the lowest hygrometric readings :—

TABLE IV.

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb	25°·0	26°·0	23°·2	38°·8	46°·6	47°·0	44°·4	45°·0	48°·7	21°·5	26°·1	29°·0
Wet Bulb	18·0	19·0	16·8	30·0	33·0	37·8	35·3	35·2	42·5	18·5	19·1	23·8
Dew-point	−20·5	−16·7	−22·9	18·8	16·7	27·7	24·7	23·4	35·7	−1·8	−16·3	4·9
Elastic Force	·017	·019	·014	·102	·093	·151	·133	·125	·209	·040	·017	·054
Relative Humidity (Sat.=100)	13	13	11	45	29	47	45	42	61	35	14	34
Day of Month	9	23	12	24	31	26	17	23	6	26	3	1

Of these lowest monthly humidities the lowest occurred on March 12, when the dew-point was −22°·9, the elastic force of vapour ·014 inch, and relative humidity 11. Very low humidities also occurred in January, February, and November. No low humidities were recorded in September, the lowest being on the 6th, when the dew-point was 35°·7, and the humidity 61, and in this month the sunshine was small, being only 29 hours, which is the smallest recorded in this month since 1885, when only 25 hours were recorded.

At the Ben Nevis Observatory the mean percentage of cloud covering the sky was 83, which is the average, the maximum being 92 in March and April and the minimum 56 in May; and at Fort William the mean was 77, the maximum being 87 in February and the minimum 54 in May. It will be noted that in the anticyclonic months of January, February, May, and November, the sky at the top was much more clear of cloud as compared with the foot of the mountain than is usually the case.

The mean rainband (scale 0–8) observation at the top was 2·3 for the year, the highest being 3·3 in July, and the lowest 1·6 in November ; and at Fort William 4·0 for the year, the highest being 5·4 in September, and the lowest 3·4 in October.

The mean hourly velocity of the wind at the top of Ben Nevis was 12 miles for the year, being the lowest velocity of any year since the observations began. The maximum mean monthly velocity was 18 miles an hour in December, and the minimum only 6 miles in June. For the three summer months, June, July, and August, the mean was at the rate of 9 miles per hour, but for the three winter months, December, January, and February, it was 15 miles per hour. These are respectively the lowest mean summer and the lowest mean winter velocities of the wind hitherto recorded at this Observatory.

The rainfall for the year at the top of Ben Nevis was 133·56 inches, being 15·56 inches greater than the rainfall of 1895. It was, however, 11·95 inches under the average of the past observations. The highest monthly amount was 19·54 inches in March, and the lowest 2·91 inches in May, being the smallest rainfall of any previous May. The heaviest fall on any single day was 2·94 inches on January 17, which is absolutely the least daily maximum fall yet recorded for any year.

On the top rain fell on 259 days, and at Fort William on 237 days, these numbers of days being the average rainy days at the two Observatories. At the top the maximum number of rainy days was 26 in March, April, and October; and at Fort William, 24 in January, March, and December. The minimum number of days of rain at the top was 12 days in May, and at Fort William 7 days, also in May.

During the year the number of days on which an inch of rain, or more, was precipitated was 44 at the top and 16 at Fort William; at the latter place an inch of rain was not reached on any day of April, May, June, July and November, but at the top, on the other hand, this amount was exceeded on 7 days of March, while May had only one such day.

Auroras are reported to have been observed on the following dates:— January 3, 4, 5, 6, 7, 9, 22, 29, 30, 31; February 2, 3, 12, 13, 17, 18, 19; March 11, 12, 13, 14, 23, 30, 31; April 14, 15; May 2, 3, 4, 11, 17; September 4; October 11, 13, 14, 15, 17; November 8.

St. Elmo's Fire was seen on January 12, 27; June 20; October 5; December 26.

The Zodiacal Light, March 12, 13.

Thunder and lightning was reported on January 20; April 10; June 4; September 16.

Lightning only, September 14; December 31.

It was intimated in last year's Report that an intermediate station had been established on Ben Nevis, at a height of 2,322 feet, or nearly midway in height between the two Observatories. This temporary station was established for the purpose of ascertaining with greater precision than has hitherto been possible the extent to which anticyclones descend on the mountain; but more particularly the relations of pressure, temperature, humidity, rainfall, cloud, and wind at this intermediate station with the observations at Fort William and on the summit of Ben Nevis. The three stations are in a line with each other, and the heights are 4,406, 2,322, and 42 feet. The observations were made by Mr. Muir, of the Royal High School of Edinburgh, during September. A report on the observations was prepared by Mr. Muir and read by him at a Meeting of the Royal Society of Edinburgh last winter. The observations at this intermediate station have been again resumed this year, and arrangements have been made for a continuous record of observations from July 19 to September 30. This year the weather fortunately has hitherto (till

August 9) been mostly anticyclonic, being the type of weather so much desired for the observations needed in carrying out the important inquiries referred to above.

During the past year much of the time of the office in Edinburgh, aided by Mr. Ormond and the staff on Ben Nevis, has been spent in preparing for the press the whole of the observations, hourly and otherwise, made at the two Observatories from January 1888 to 1896. These observations, now ready for press, will fill two large quarto volumes. A discussion of the observations from December 1883, when they commenced, to December 1896, is in progress, which, it is expected, will be finished in the spring of next year.

Among the separate parts of this large discussion, already completed, are the mean hourly variation of the barometer, and the temperature, for the months and the year, at each of the two Observatories for the same terms of years, from August 1890 to December 1896, or six years and five months. The two sets of curves are therefore strictly comparable, being calculated for the same time. The results are given in the four Tables, V., VI., VII., and VIII., at the end of this Report.

The hourly observations made by the Swedish expedition at Jan Mayen in 1882–83, particularly the hourly barometric observations in clear and clouded weather respectively, together with the observations made on the open sea of the Arctic Ocean by the same expedition. The results, in clear and in clouded weather, are of the greatest possible interest in their relation to similar inquiries made with the observations of the two Ben Nevis Observatories, and of other observatories in different parts of the world, and reported on by your Committee in their Annual Reports for several years past.

But an equally great interest attaches to the discussion of these barometric observations made on the open sea of the Arctic regions in 1882–83, together with similar observations made by Professor Mohn in the Arctic Ocean in the summer months of 1876–77–78. From the observations made on this ocean at a season when the sun is constantly above the horizon, it is shown that there is only one daily maximum and one minimum of pressure closely agreeing with the diurnal curve of temperature. At the same season the small island of Jan Mayen presents in its diurnal curves of pressure the usual double maxima and minima.

The same discussion opens up important inquiries as to the different effects on the diurnal curves of pressure according as the terrestrial radiation from the earth's surface towards space, proceeds from extended fields of snow, bare rock or soil, grass, or sheets of water.

The hourly observations of the rainfall and snowfall at the two Observatories have been discussed, from which it is shown that the diurnal curves have two maxima and two minima, and that the summer and winter curves present striking differences.

The work of preparing maps, showing for each day the amount of the rainfall at 120 stations well distributed over Scotland, is steadily progressing. As the work proceeds it becomes more and more apparent that as regards large rainfalls with west wind—(1) over all Scotland ; (2) over western districts only ; (3) north of the Grampians only ; (4) south of the Grampians only ; or with east winds—(5) over all Scotland, an exceedingly rare occurrence ; (6) over eastern districts only ; (7) over only a narrow strip on the coast ; (8) over the foreshores only of the Firth of Forth, the Moray Firth and the Pentland Firth, these inquiries receive much elucida-

tion from the contrasted hourly observations of the two Ben Nevis Observatories, particularly the observations of dry and wet bulb hygrometers.

TABLE V.—*Hourly Variation of the Barometer at the Ben Nevis Observatory. Mean of* 6–7 *years from August* 1890 *to December* 1896. *Height,* 4,406 *feet. The figures represent thousandths of an inch.*

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	−1	1	1	−5	−3	−2	−2	−2	2	−3	1	3	−1
2 "	−3	−3	−5	−10	−8	−8	−7	−8	−3	−5	−3	−0	−5
3 "	−5	−7	−11	−14	−13	−13	−12	−13	−9	−11	−6	−3	−10
4 "	−11	−10	−16	−17	−17	−17	−15	−19	−13	−15	−9	−8	−14
5 "	−14	−9	−15	−17	−18	−16	−16	−21	−16	−13	−10	−11	−14
6 "	−18	−9	−13	−13	−14	−14	−14	−18	−14	−12	−9	−11	−13
7 "	−15	−7	−9	−8	−11	−10	−10	−14	−10	−8	−6	−9	−10
8 "	−10	−2	−4	−3	−7	−5	−5	−9	−8	−2	1	−4	−5
9 "	−5	3	−1	−0	−4	−2	−2	−5	−4	2	5	1	−1
10 "	−0	4	1	5	0	0	0	−1	−1	5	9	6	2
11 "	4	7	5	8	3	3	4	2	1	8	9	9	5
Noon	4	7	7	10	6	5	6	7	3	8	5	4	6
1 P.M.	0	4	8	12	9	7	8	10	7	7	0	−1	6
2 "	−1	0	4	11	11	8	9	10	5	5	−4	−4	4
3 "	−4	−0	1	8	10	6	7	9	3	3	−7	−5	3
4 "	−0	−2	0	6	8	6	6	7	2	1	−5	−2	2
5 "	5	0	3	5	6	5	5	7	2	4	−1	−1	3
6 "	8	5	5	5	5	4	4	6	3	7	2	1	5
7 "	11	6	9	5	5	6	5	7	6	8	3	4	6
8 "	13	6	9	6	7	6	4	10	10	7	4	7	7
9 "	14	5	9	5	9	10	8	11	10	5	5	8	8
10 "	12	6	8	4	8	10	8	10	10	2	6	7	8
11 "	9	5	6	1	5	8	7	7	9	0	6	8	6
Midnight	4	4	3	−2	2	3	3	3	5	0	4	7	3
Inches 25·+	·228	·294	·183	·388	·448	·471	·391	·188	·371	·209	·255	·168	·300

TABLE VI.—*Hourly Variation of the Temperature at the Ben Nevis Observatory. Mean of* 6–7 *years from August* 1890 *to December* 1896. *Height,* 4,406 *feet. The figures represent tenths of a degree Fahrenheit.*

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	−1	−3	−5	−11	−13	−17	−13	−8	−7	−2	−2	−2	−7
2 "	−2	−3	−6	−11	−15	−19	−15	−10	−9	−2	−1	−1	−8
3 "	−2	−4	−6	−12	−17	−22	−17	−12	−10	−4	−0	−2	−9
4 "	−1	−4	−8	−14	−20	−22	−19	−13	−11	−5	−1	−1	−10
5 "	−2	−4	−9	−15	−19	−20	−18	−14	−12	−6	−1	−1	−10
6 "	−1	−5	−11	−12	−16	−17	−17	−14	−12	−7	−2	−2	−10
7 "	−2	−6	−11	−9	−11	−12	−13	−11	−10	−8	−5	−2	−8
8 "	−2	−8	−6	−5	−7	−6	−8	−8	−6	−5	−5	−2	−6
9 "	−2	−5	−1	1	−0	−0	−2	−3	−1	−2	−2	−2	−2
10 "	0	−1	3	7	7	6	4	3	4	2	0	0	3
11 "	2	4	7	10	14	11	10	8	8	5	2	3	7
Noon	3	8	10	14	19	16	15	12	12	8	4	5	10
1 P.M.	5	10	13	19	23	21	19	15	14	9	4	5	13
2 "	4	10	13	18	24	24	21	17	16	9	5	3	14
3 "	1	9	13	18	24	25	23	18	16	8	4	2	13
4 "	0	7	10	15	20	24	20	16	13	4	1	1	11
5 "	0	2	4	10	16	20	17	12	10	2	0	1	8
6 "	0	0	0	6	10	15	11	9	4	0	0	0	5
7 "	−1	−0	−1	−1	4	10	6	4	1	−1	−1	0	2
8 "	−0	−0	−2	−4	−2	2	2	−0	−0	−1	1	−0	−0
9 "	−0	−1	−2	−5	−5	−3	−2	−2	−3	−1	−0	−1	−2
10 "	−1	−1	−2	−7	−8	−8	−6	−5	−5	−1	−0	−0	−4
11 "	−1	−0	−3	−8	−11	−12	−8	−7	−6	−2	−0	−1	−5
Midnight	−0	−1	−4	−10	−12	−14	−10	−9	−6	−2	−1	−2	−6
Mean	22·6	24·6	24·5	29·6	34·1	40·1	40·9	39·9	38·4	30·1	28·6	25·0	31·5

TABLE VII.—*Hourly Variation of the Barometer at Fort William. Mean of* 6–7 *years from August* 1890 *to December* 1896. *Height,* 42 *feet. The figures represent thousandths of an inch.*

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	2	3	4	4	9	10	8	4	6	0	0	2	4
2 "	0	2	1	2	8	8	5	0	4	− 4	− 1	1	2
3 "	− 4	− 4	− 7	− 2	2	4	0	− 6	− 3	− 9	− 6	− 3	− 3
4 "	− 9	− 5	− 9	− 2	2	4	− 0	− 8	− 5	−10	− 8	− 8	− 5
5 "	−15	− 8	− 8	− 2	2	4	− 0	− 9	− 8	−11	− 9	−12	− 6
6 "	−18	− 5	− 4	4	7	8	4	− 5	− 4	− 6	− 7	−11	− 3
7 "	−17	− 3	− 2	7	7	8	6	− 3	− 1	− 3	− 5	− 9	− 1
8 "	−10	6	4	11	9	10	7	1	2	6	5	− 2	4
9 "	− 5	7	5	9	6	6	5	2	3	7	8	3	5
10 "	3	10	7	10	3	4	4	3	4	9	13	10	7
11 "	4	8	6	5	− 2	− 0	0	1	− 1	7	13	11	4
Noon	1	7	5	3	− 5	− 2	0	0	0	4	7	5	2
1 P.M.	− 5	− 2	− 0	− 3	− 9	− 7	− 4	− 2	− 3	− 1	− 0	− 2	− 3
2 "	− 4	− 8	− 5	− 6	−11	− 9	− 5	− 1	− 5	− 4	− 6	− 7	− 6
3 "	− 4	−14	−10	−14	−14	−14	− 9	− 6	−11	− 7	−10	− 9	−10
4 "	1	−12	−10	−15	−15	−16	−12	− 6	−11	− 6	− 8	− 4	−10
5 "	2	−10	−11	−16	−16	−19	−14	− 7	−12	− 5	− 6	− 4	−10
6 "	8	− 1	− 4	−12	−12	−16	−11	− 4	− 6	3	− 1	0	− 5
7 "	10	2	0	− 8	− 8	−12	− 9	− 1	− 2	4	0	1	− 2
8 "	15	4	7	0	− 0	− 4	− 2	7	8	7	3	6	4
9 "	13	4	8	4	6	3	4	10	10	6	3	6	6
10 "	14	6	11	6	12	10	10	13	13	4	6	10	10
11 "	9	5	10	6	12	11	10	11	12	2	4	7	8
Midnight	8	8	9	7	12	13	10	9	10	1	5	7	8
Inches 29·+	·874	·929	·796	·983	1·006	·976	·875	·811	·876	·767	·842	·779	·876

TABLE VIII.—*Hourly Variation of the Temperature at Fort William. Mean of* 6–7 *years from August* 1890 *to December* 1896. *Height,* 42 *feet. The figures represent tenths of a degree Fahrenheit.*

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	− 2	− 8	−18	−32	−40	−42	−32	−26	−19	−13	− 7	− 3	−20
2 "	− 4	−11	−21	−38	−46	−49	−36	−29	−23	−16	− 9	− 5	−24
3 "	− 4	−11	−24	−41	−49	−53	−39	−21	−25	−17	− 8	− 5	−26
4 "	− 5	−13	−26	−45	−53	−56	−42	−33	−29	−19	− 8	− 6	−28
5 "	− 5	−14	−26	−47	−57	−53	−40	−34	−29	−20	− 8	− 6	−28
6 "	− 6	−16	−30	−48	−45	−41	−33	−32	−32	−21	− 9	− 6	−27
7 "	− 5	−15	−29	−37	−28	−26	−20	−23	−27	−20	− 7	− 5	−20
8 "	− 6	−16	−26	−22	−15	−12	− 9	−12	−18	−18	− 9	− 3	−14
9 "	− 5	−12	−10	− 4	3	5	5	2	− 5	− 9	− 5	− 2	− 3
10 "	− 4	− 6	− 0	11	15	17	14	11	7	1	− 1	− 2	5
11 "	1	5	13	24	29	28	23	20	19	15	7	3	16
Noon	6	12	23	35	36	33	28	26	26	22	12	6	22
1 P.M.	12	20	32	45	45	41	36	32	32	29	16	10	29
2 "	12	25	35	50	50	46	40	35	36	31	17	11	32
3 "	10	28	39	55	54	51	43	40	41	32	16	10	35
4 "	5	24	38	52	52	51	40	37	37	28	11	7	32
5 "	3	17	33	46	48	50	37	33	32	17	7	5	27
6 "	1	9	21	37	40	44	30	25	19	7	3	3	20
7 "	1	4	10	20	28	34	22	12	8	3	2	2	12
8 "	− 1	0	3	5	8	14	6	1	− 1	− 2	− 1	0	3
9 "	− 0	− 3	− 2	− 5	− 6	− 4	− 5	− 6	− 6	− 3	− 2	− 0	− 4
10 "	− 0	− 5	− 8	−14	−17	−16	−15	−12	−12	− 6	− 4	− 1	− 9
11 "	− 0	− 6	−12	−21	−26	−26	−21	−17	−15	− 8	− 4	− 3	−13
Midnight	− 2	− 8	−15	−28	−34	−34	−28	−22	−18	−13	− 6	− 4	−18
Mean													

Electrolysis and Electro-chemistry.—Report of the Committee, consisting of Mr. W. N. SHAW (*Chairman*), Mr. E. H. GRIFFITHS, Rev. T. C. FITZPATRICK, Mr. W. C. D. WHETHAM (*Secretary*), *on the present state of our knowledge in Electrolysis and Electro-chemistry.*

THE experiments upon the electrical properties of solutions, in relation to their thermal properties, towards the expenses of which a grant of 50*l.* was made, are in progress. The apparatus for the measurement of the resistance of solutions has been designed, constructed, and tested. It has been proved to work satisfactorily by test experiments with pure water and with solutions of potassium chloride.

The cost of the apparatus, the essential parts of which had to be made of platinum, has exceeded the amount of the grant.

The expenses incidental to the completion of the experiments are estimated by the Secretary at 35*l.*, and the Committee desire that that sum be placed at their disposal in the ensuing year.

The section of the report on electrolysis treating of the theory of migration of ions and of specific ionic velocities prepared by Mr. Whetham last year is printed as an appendix to this report.

The Committee regret that the pressure of other engagements has prevented further progress with the compilation of the report.

The Committee ask for reappointment, with a grant of 35*l.*

APPENDIX.

(*f*) *The Theory of the Migration of Ions and of Specific Ionic Velocities. By* W. C. DAMPIER WHETHAM, *M.A.*

The liberation of the products of electrolysis at the electrodes, and at the electrodes only, shows that a continuous passage of the opposite ions in opposite directions through the liquid must be going on. Whether the ions are free from each other during their passage, or accomplish their journey by means of continual decomposition and recombination of molecules, does not matter for our present purpose. The numbers of the ions in the middle portion of the liquid do not change, but, while the current passes, a constant excess of anions is delivered at the anode, and of kations at the kathode.

If the opposite ions move with equal velocities, the result of the passage of the current will be that, while the composition of the middle portion of the solution remains unaltered, the products of the decomposition, which appear at the electrodes, are taken in equal proportions from the solution surrounding the anode, and from that round the kathode.

If, however, one of the ions travels faster than the other, it will get away from the portion of the solution whence it comes more quickly than the other ion enters. The concentration of this region will therefore fall faster than that of the liquid round the other electrode, and the ratio

between the rates at which salt is taken from the neighbourhoods of the anode and kathode gives also the ratio between the velocities of the kation and anion.

Thus, by measuring the contents of vessels containing the electrodes before and after the passage of the current, we can determine the ratio between the velocities of the two ions in any given case of electrolysis. Many such investigations have been made by Hittorf,[1] Lenz,[2] Loeb and Nernst,[3] and Kistiakowsky.[4] An account of their methods and results will be found in Professor Ostwald's 'Lehrbuch der Allgemeinen Chemie,' 2nd edition, vol. ii., p. 598, and most of the numerical results obtained are included in a table compiled by T. C. Fitzpatrick and published in the previous portion of this report, which appeared in 1893.

A further step was taken by Professor F. Kohlrausch in the year 1879.[5] Kohlrausch introduced a satisfactory method of measuring the conductivity of electrolytes by means of alternating currents, and showed that, from a knowledge of the conductivity, the sum of the opposite ionic velocities (*i.e.* the velocity with which the opposite streams of ions travel past each other) could be calculated.

Faraday's work showed that the passage of a definite quantity of electricity through the solution involves the decomposition of a definite mass of electrolyte, which varies as its chemically equivalent weight and as the quantity of electricity. Thus the quantity of electricity which must pass in order to decompose the equivalent weight of an electrolyte in grams is independent of the nature of the electrolyte.

We may therefore represent the facts by considering the process of electrolysis to be a kind of convection, the ions moving through the solution and carrying their charges with them. Each univalent ion may be supposed to carry a certain definite charge, which we may take to be the true natural unit of electricity; each divalent ion carries twice as much, and so on.

Let us take, as an example, the case of an aqueous solution of hydrochloric acid whose concentration is m gram-equivalents per cubic centimetre.

There will then be m gram-equivalents of hydrogen ions and the same number of chlorine ions in this volume. Let us suppose that on each gram-equivalent of hydrogen there reside $+q$ units of electricity, and on each gram-equivalent of chlorine ions $-q$ units. If u denote the average velocity of the hydrogen ions, the positive charge carried per second across unit area normal to the flow is $m\,q\,u$. Similarly, if v be the average velocity of the chlorine ions, the negative charge carried in the opposite direction is $m\,q\,v$. But positive electricity moving in one direction is equivalent to negative electricity moving in the other, so that the total current, C, is $m\,q\,(u+v)$.

Now let us consider the amounts of hydrogen and chlorine liberated at the electrodes by this current.[6] At the kathode, if the chlorine ions were at rest, the excess of hydrogen ions would be simply those arriving in one

[1] *Pogg. Ann.* 1853–9, vol. lxxxix. pp. 177; xcviii. p. 1; ciii. p. 1; cvi. pp. 337, 513.
[2] *Mem. Petersb. Ak.* 1882, vol. ix. p. 30.
[3] *Zeits. physikal. Chem.* 1883, vol. ii. p. 948.
[4] *Zeits. physikal. Chem.* 1890, vol. vi. p. 97.
[5] *Wied. Ann.* vol. vi. p. 160.
[6] This modification of Professor Lodge's method of developing Kohlrausch's equation was suggested to the writer by Professor G. F. FitzGerald.

second, viz. $m\,u$. But, since the chlorine ions move also, a further separation occurs, and $m\,v$ hydrogen ions are left without partners. The total number of gram-equivalents liberated is therefore $m(u+v)$. This must, by Faraday's law, be equal to ηC, where η denotes the electro-chemical equivalent of hydrogen. Thus we get

$$m(u+v)=\eta C=\eta\,m\,q(u+v),$$

and it follows that the charge, q, on one gram-equivalent of *each* kind of ion is equal to $1/\eta$.

We know that Ohm's law holds good for electrolytes, so that the current C is also given by $k\,.\,dP/dx$, where k denotes the conductivity of the solution, and dP/dx the potential gradient, *i.e.* the fall in potential per unit length along the lines of current flow.

Thus
$$\frac{m}{\eta}(u+v)=k\,.\,dP/dx;$$
$$\therefore\ u+v=\eta\frac{k}{m}\cdot\frac{dP}{dx}.$$

Now η is $1{\cdot}0352+10^{-4}$, and the concentration of a solution is usually expressed in terms of the number, n, of gram-equivalents per litre instead of per cubic centimetre.

Therefore
$$u+v=1{\cdot}0352\times10^{-1}\ \frac{k}{n}\cdot\frac{dP}{dx}.$$

When the potential gradient is one volt (10^8 C.G.S. units) per centimetre, this becomes

$$u+v=1{\cdot}0352\times10^{7}\times\frac{k}{n}.$$

Thus, by measuring in C.G.S. units the conductivity of a solution of known concentration, the relative velocity of its ions can at once be deduced. It is true that, in this investigation, we have assumed that all the contents of the solution are actively concerned in the electrolysis—an idea which seems to be disproved by the diminution in the molecular conductivity with increasing concentration. But although, at any instant, only a part of the electrolyte is active, we must imagine that each portion will become active in turn, two given ions of opposite kinds being sometimes free (*i.e.* active) and sometimes paired (*i.e.* inactive). The immediate effect, therefore, of the decrease in ionisation, with increasing concentration, is to diminish the relative velocity of the ions, and this diminution will reduce the molecular conductivity in accordance with the equation.

Since Hittorf's numbers give us the ratio of the ionic velocities, we can deduce the absolute values of u and v from this theory. Thus, for instance, the molecular conductivity of a solution of potassium chloride containing one-tenth of a gram-equivalent per litre is 1113×10^{-13} C.G.S. units at 18° C.

$$\therefore\ u+v=1{\cdot}0352\times10^{7}\times1113\times10^{-13},$$
$$=1{\cdot}153\times10^{-3}=0{\cdot}001153\ \text{cm. per sec.}$$

Hittorf's experiments show us that the ratio of the velocity of the anion to that of the kation in this solution is ·51 : ·49. The absolute velocity of the chlorine ion under unit potential gradient is therefore 0·000589 cm. per sec., and that of the potassium ion 0·000564 cm. per sec. Similar calculations can be made for solutions of other con-

centrations. The following table shows Kohlrausch's latest[1] values for the ionic velocities of three chlorides of alkali metals in 10^{-6} cms. per sec. at 18° C., calculated for a potential gradient of 1 volt per cm. :—

n	KCl			NaCl			LiCl		
	$u+v$	u	v	$u+v$	u	v	$u+v$	u	v
0	1350	660	690	1140	450	690	1050	360	690
0·0001	1335	654	681	1129	448	681	1037	356	681
·001	1313	643	670	1110	440	670	1013	343	670
·01	1263	619	644	1059	415	644	962	318	644
·03	1218	597	621	1013	390	623	917	298	619
·1	1153	564	589	952	360	592	853	259	594
·3	1088	531	557	876	324	552	774	217	557
1·0	1011	491	520	765	278	487	651	169	482
3·0	911	442	469	582	206	376	463	115	348
5·0	—	—	—	438	153	285	334	80	254
10·0	—	—	—	—	—	—	117	25	92

These numbers clearly show the increase in ionic velocity as the dilution gets greater. Moreover, if we compare the values for the chlorine ion obtained from observations on these three different salts, we see that, as the solutions get very weak, the velocity of the chlorine ion becomes the same in all of them. Similar phenomena appear in other cases, and, in general, we may say that, at great dilution, the velocity of an ion is independent of the nature of the other ion present. This at once leads to the idea of *specific* ionic velocities, the values of which for different ions are given by Kohlrausch in the following table :—

K . .	66 × 10^{-5} cms. per sec.	Cl . .	69 × 10^{-5} cms. per sec.
Na . .	45 " "	I . .	69 " "
Li . .	36 " "	NO_3 . .	64 " "
NH_4 . .	66 " "	OH . .	182 " "
H . .	320 " "	$C_2H_3O_2$.	36 " "
Ag . .	57 " "	$C_3H_5O_2$.	33 " "

Having once obtained these numbers, we can calculate the molecular conductivity of the dilute solution of any salt, and the comparison of such values with observation furnished the first confirmation of Kohlrausch's theory. Some exceptions, however, are known. Thus, acetic acid and ammonia give solutions of much lower conductivity than is indicated by the sum of the specific ionic velocities of their ions as determined from other compounds.

Professor Oliver Lodge was the first to directly measure the velocity of an ion.[2] In a horizontal glass tube connecting two vessels filled with dilute sulphuric acid, he placed a solution of sodium chloride in solid agar-agar jelly. This solid solution was made alkaline with a trace of caustic soda to bring out the red colour of a little phenol-phthalein added as indicator. A current was then passed from one vessel to the other along the tube. The hydrogen ions from the anode vessel of acid were thus carried along the tube, forming hydrochloric acid as they travelled, and decolorising the phenol-phthalein. By this method the velocity of the

[1] *Wied. Ann.* 1893, vol. l. p. 385.
[2] *British Association Report*, 1886 p. 389.

hydrogen ion through a jelly solution under a known potential gradient could be observed. The results of three experiments gave 0·0029, 0·0026, and 0·0024 cm. per sec. as the velocity of the hydrogen ion for a potential gradient of one volt per centimetre. Kohlrausch's number is 0·0032 for the dilution corresponding to maximum conductivity. Lodge does not mention the concentration of his solution, but it was probably large enough to appreciably reduce the velocity.

When the current density at the kathode of a solution of copper sulphate exceeds a certain limit, the copper is deposited as a brown or black hydride. C. L. Weber [1] explained this as due to the inability of the copper ions to migrate fast enough to keep up the supply for carrying the current, part of which will consequently be conveyed by sulphuric acid formed by the action of SO_4 ions on the water. By measuring the limiting current density and the conductivity of the solution, he estimated the speed of the copper ions when they could travel just fast enough to carry all the current, and hence he deduced their specific velocity. Similar methods were used for solutions of cadmium sulphate and zinc nitrate. The copper sulphate measurements were repeated with an improved apparatus by Sheldon and Downing.[2] This method does not appear to be a very good one, for the dilution of the liquid round the kathode makes it impossible to accurately determine the conductivity of the solution concerned. This source of error will make the deduced velocities too great.

Direct determinations of the velocities of a few other ions have been made in another way by the present writer.[3] Two solutions, having one ion in common, of equivalent concentrations, different densities, different colours, and nearly equal specific resistances, were placed one over the other in a vertical glass tube. In one case, for example, decinormal solutions of potassium carbonate and potassium bichromate were used. The colour of the latter is due to the presence of the bichromate group, Cr_2O_7. When a current was passed across the junction, the anions Cl and Cr_2O_7 travelled in the direction opposite to that of the current, and their velocity could be determined by measuring the rate at which the colour boundary moved. Similar experiments were made with alcoholic solutions of cobalt salts, in which the velocities of the ions were found to be much less than in water. The behaviour of agar jelly was then investigated, and the velocity of an ion was shown to be very little less through a solid jelly than in an ordinary liquid solution. The velocities could therefore be measured by tracing the change in colour of an indicator or the formation of a precipitate. Thus decinormal jelly solutions of barium chloride and sodium chloride, the latter containing a trace of sodium sulphate, were placed in contact. Under the influence of an electromotive force, the barium ions moved up the tube, and their presence was shown by the trace of insoluble barium sulphate formed.

The following table shows the velocities of all ions which have been experimentally determined. A comparison is given with their values as calculated, for the same concentration, on Kohlrausch's theory.

[1] *Zeits. physikal. Chem.* 1889, vol. iv. p. 182.
[2] *Physical Review.* 1893, vol. i. p. 51.
[3] *Phil. Trans.* 1893, vol. clxxxiv. A, p. 337; *Phil. Mag.*, October, 1894; *Phil. Trans.* 1895, vol. clxxxvi. A, p. 507.

Name of Ion	Concentration of solution in gram-equivalents per litre	Specific Ionic velocity in centimetres per second		Observer
		Calculated from Kohlrausch's theory	Observed	
Hydrogen in chlorides . .	—	0·0028	0·0026	O. J. Lodge
„ in acetates . .	0·07	0·000048	0·000065	W. C. D. Whetham
Zinc	0·003	0·00030	0·00051	C. L. Weber
Cadmium	0·007	0·00031	0·00051	„
Copper (in sulphates) . .	0·01	0·00030	0·00042	„
„ „ . .	0·1	0·00017	0·00045	Sheldon and Downing
„ (in chlorides) . .	0·1	—	0·00031	W. C. D. Whetham
Barium	0·1	0·00037	0·00039	„
Calcium	0·1	0·00029	0·00035	„
Silver	0·1	0·00046	0·00049	„
Sulphate group (SO_4) . .	0·1	0·00049	0·00045	„
Bichromate group (Cr_2O_7) .	0·1	0·00047	0·00047	„
Cobalt (in alcoholic $CoCl_2$) .	0·05	—	0·000022	„
„ („ „ $Co(NO_3)_2$)	0·05	—	0·000044	„
Chlorine (in alcoholic $CoCl_2$).	0·05	—	0·000026	„
Nitrate group (NO_3) (in alcoholic $Co(NO_3)_2$) . . .	0·05	—	0·000035	„

NOTE.—The migration data for solutions of copper chloride are not known. The specific ionic velocity of copper at infinite dilution (when it would be independent of the nature of the combination) is given by Kohlrausch as 0·00031, but in a solution of the strength used it would be considerably less. The sum of the ionic velocities of cobalt chloride in alcohol, as calculated from the conductivity, is 0·000060 cm. per sec., and that of cobalt nitrate 0·000079. These numbers are to be compared with the sum of the observed velocities given in the table—namely, 0·000048 and 0·000079 respectively.

The agreement will be seen to be quite as good as can be expected. The number for the hydrogen ion in acetic acid is especially interesting, for it shows that, in cases where the conductivity is abnormally low, such as those of acetic acid and ammonia, the ionic velocities are reduced in the same proportion. In such cases the mean free time of the ions (adopting the language of the dissociation theory) is small as compared with their mean paired time. They can move forward only while they are free, and thus their velocity is reduced, and, with it, the conductivity of the solution. Kohlrausch's theory, therefore, probably holds good in every case, even if alcohol be the solvent, if the proper values are given to the ionic velocities—*i.e.* the values which express the velocities with which the ions actually move in the solution of the strength taken, and under the conditions of the experiment.

If we restrict ourselves to the *specific* ionic velocities—the velocities at infinite dilution—we must introduce a factor measuring the ratio of the actual to the limiting relative velocity of the ions. If we call this ratio a, and take u and v to denote the *specific* ionic velocities, we can express the conductivity by the equation

$$a\,(u+v) = 1{\cdot}0352 \times 10^7 \frac{k}{n}$$

or

$$\frac{k}{n} = a\,(u+v) \times \frac{10^{-7}}{1{\cdot}0352}$$

The coefficient a is thus given by the ratio between the actual molecular conductivity of the solution and its value at infinite dilution, and can therefore be readily determined.

The velocities of the ions may be reduced by an increase in frictional resistance, by a diminution in the fraction of the dissolved substance which is, at any moment, active, or by a combination of both these causes. In dilute solutions the resistance offered by the liquid to the passage of the ions through it is probably sensibly the same as in pure water ; but when the proportion of non-ionised molecules becomes considerable, we cannot assume that this is the case. Arrhenius' experiments on the conductivity of jelly solutions,[1] while they certainly show that the ionic friction does not depend on the molar viscosity of the medium, do not prove, as usually seems to be assumed, that it is not affected by the addition of more of the electrolyte, which would cause a molecular change.

While the solution is dilute enough for the friction to be taken as constant, however, the coefficient a can be given a very simple physical meaning. The fraction which expresses the ratio of the actual to the limiting velocity of the ions must then also express the fraction of its time during which, on the average, any ion remains active ; that is, it must express the fractional number of molecules which are, at any moment, in a state of activity. This fractional number may be called the coefficient of ionisation.

Thus, although we can, if we like, always put Kohlrausch's theory in the form shown in our last equation, the constant a will only have a definite physical meaning when the solution is so dilute that the ionic viscosity keeps constant. This caution is necessary, for it seems to be universally assumed that a, as deduced from the ratio of the actual to the limiting conductivity, always expresses the ionisation of the solution, whatever its concentration may be, although for fairly strong solutions no convincing evidence has been adduced in favour of the assumption made. It is possible that some of the discrepancies between the ionisation as found from the conductivity and as deduced in other ways—as, for example, from the depression of the freezing point—may be due to this cause.

On the other hand, the equation given on p. 229, in which u and v denote the actual velocities of the ions under the conditions of the experiment, probably holds good whatever be the concentration of the solution, and this gives the simplest and most certain form of Kohlrausch's theory.

The fact that the molecular conductivity of aqueous solutions becomes, in general, constant as the dilution gets very great shows that the velocities of the ions must then become independent of the concentration of the solution. This seems to offer strong evidence in favour of the view that the ions are free from each other, which is also indicated by the fact that the specific velocity of an ion at great dilution comes out the same whatever be the nature of the other ion present.

If the ions are not free, the alternative is to suppose that they move forward by taking advantage of a collision between two solute molecules by means of which an interchange of ions may occur, and each makes a step in advance. Now the frequency with which such collisions would happen must vary as the square of the concentration ; and, since the quantity of electricity conveyed must also depend on the number of ions present, the conductivity would vary as the cube of the concentration. The motion of the ions cannot, therefore, depend on collisions between the molecules of

[1] *British Association Report,* 1886, p. 344.

dissolved matter. It must be an independent motion, and the ions must be dissociated from each other. It will be noticed that there is nothing to show that the ions are not combined with solvent molecules, and there seems reason to suppose that such may be the case.

We may conclude, from the experimental confirmation described above, that the velocity of an ion, as calculated by Kohlrausch's theory from the conductivity, really does represent the actual speed with which, on the average, the ion makes its way through the solution. We can therefore apply the theory with confidence to cases in which the experimental confirmation would be difficult or impossible.

If we know the specific velocity of any one ion, we can, from the conductivity of very dilute solutions, at once deduce the velocity of any other ion with which it may be combined, without having to determine the migration constant of the compound, which is a matter involving considerable trouble. Thus, taking the specific ionic velocity of hydrogen as 0·0032 cm. per second, we can, by determining the conductivity of dilute solutions of any acid, at once find the specific velocity of the acid radicle involved. Or, again, since we know the specific velocity of the silver ion, we can find the velocities of a series of acid radicles at great dilution by measuring the conductivity of their silver salts.

By such methods Ostwald, Bredig, and other observers have found the specific velocities of many ions both of inorganic and organic compounds, and examined the relation between constitution and ionic velocity. A full account of such data will be found in a paper by Bredig in vol. xiii. of the 'Zeitschrift für physikalische Chemie,' p. 191. The velocities are calculated from the conductivities measured in terms of mercury units, and so must be multiplied by 110×10^{-7} if they are wanted in centimetres per second.

The velocity of elementary ions is found to be a periodic function of the atomic weight, similar elements lying on similar portions of the curve. The curve much resembles that giving the relation between atomic weight and viscosity in solution. For complex ions the velocity is largely an additive property; to a continuous additive change in the composition of the ion corresponds a continuous but decreasing change in the velocity. Thus Ostwald's results for the anions of the formic acid series give

			Diff. for CH_2
Formic acid	HCO_2	51·2	
			−12·9
Acetic "	$H_3C_2O_2$	38·3	
			− 4·0
Propionic "	$H_5C_3O_2$	34·3	
			− 3·5
Butyric "	$H_7C_4O_2$	30·8	
			− 2·0
Valeric "	$H_9C_5O_2$	28·8	
			− 1·4
Caproic "	$H_{11}C_6O_2$	27·4	

Bredig finds similar relations for every such series of compounds which he examined. Isomeric ions of analogous constitution have equal velocities. A retarding effect is, in general, produced by the replacement of H by Cl, Br, I, Me, NH_2 or NO_2: of any element by an analogous one of higher atomic weight (except O and S); of NH_3 by H_2O; of $(CN)_6$ by $(C_2O_4)_3$; by the change of amines into acids; of sulphonic acids into carboxylic acids; acids into cyanamides, dicarboxylic into monocarboxylic acids; and by monamines into diamines. The additive effect is, however, largely influenced by constitution. Thus in metamerides the velocity increases with the symmetry of the ion, especially as the number of C—N unions gets greater.

Diffusion of Electrolytes.—An application of the theory of ionic velocity due to Nernst [1] and Planck [2] enables us to calculate the diffusion constant of dissolved electrolytes. According to the molecular theory, diffusion is due to the motion of the molecules of the dissolved substance through the liquid. When the dissolved molecules are uniformly distributed, the osmotic pressure will be the same everywhere throughout the solution, but if the concentration varies from point to point, the pressure will vary also. There must, then, be a relation between the rate of change of the concentration and the osmotic pressure gradient, and thus we may consider the osmotic pressure gradient to be analogous to a force driving a body through a viscous medium.

In the cases of non-electrolytes and of all non-ionised molecules this analogy completely represents the facts, and the phenomena of diffusion can be deduced from it alone. But the ions of an electrolytic solution can move independently through the liquid, even when no current flows, as the truth of Ohm's law for electrolytes indicates. They will therefore diffuse independently, and the faster ion will travel quicker into pure water in contact with a solution. The ions carry their charges with them, and, as a matter of fact, it is found that, in general, water in contact with a solution takes with respect to it a positive or negative potential, according as the positive or negative ion travels the faster.

This process will go on until the simultaneous separation of electric charges produces an electrostatic force strong enough to prevent further separation of ions. We can therefore calculate the rate at which the salt as a whole will diffuse by examining the conditions for a steady state, in which the ions diffuse at an equal rate, the faster one being restrained and the slower one urged forward by the electric forces.

Let us imagine that we have an aqueous solution of some electrolyte at the bottom of a tall glass cylinder with pure water lying above it. In a layer of liquid at a height x let the concentration (*i.e.* the number of gram-molecules per cubic centimetre) be c, and the osmotic pressure p. At a height $x + dx$ these become $c - dc$ and $p - dp$ respectively. The volume of the layer cut off by horizontal planes at these heights is qdx, where q is the area of cross-section, and this volume contains $cqdx$ gram-molecules of electrolyte. The difference of osmotic pressure between the planes is dp, so that, on our analogy, we must imagine that the force acting on the layer is $-qdp$ (the negative sign being taken because the force is in the direction in which p decreases) and the force on one gram-molecule is $-\frac{1}{c}\frac{dp}{dx}$. Now from the velocities of the two ions under unit potential gradient, as found by Kohlrausch's theory, it is easy to deduce the velocity with which they will travel when unit force acts on them. Let us call these velocities U and V for the kation and anion respectively. The actual velocities in our case will therefore be $-\frac{U}{c}\frac{dp}{dx}$ and $-\frac{V}{c}\frac{dp}{dx}$, so that the amounts passing any cross-section of the cylinder in a time dt are

$$-Uq\frac{dp}{dx}dt \text{ and} -Vq\frac{dp}{dx}dt.$$

[1] *Zeits. physikal. Chem.* vol. ii. p. 613. Account in Nernst's *Theoretische Chemie*, or Whetham's *Solution and Electrolysis.*

[2] *Wied. Ann.* 1890, vol. xl. p. 561.

If U is different from V a difference of potential is set up, the effect of which, when a steady state is reached, is to make the ions travel together. If the potential gradient is $\frac{dP}{dx}$ the numbers of the two ions which would cross, under the action of this force alone, are

$$-Uqc\frac{dP}{dx}dt \text{ and} + Vqc\frac{dP}{dx}dt.$$

Under the influence of both the osmotic and the electric forces the number of gram-equivalents which diffuse in a given time must be equal, so that we get

$$dN = -Uqdt\left(\frac{dp}{dx} + c\frac{dP}{dx}\right) = -Vqdt\left(\frac{dp}{dx} - c\frac{dP}{dx}\right);$$

or eliminating dP/dx,

$$dN = -\frac{2UV}{U+V}q\frac{dp}{dx}dt.$$

For dilute solutions we may assume that the gaseous laws hold good, so that

$$p = cRT,$$

c, the concentration, being the reciprocal of the volume in which one gram-molecule is dissolved.

$$\therefore dN = -\frac{2UV}{U+V}RTq\frac{dc}{dx}dt.$$

We shall need the intermediate steps of this investigation when we consider Nernst's account of contact differences of potential; but it has been pointed out to the writer by Professor Fitzgerald that, when the electrostatic forces make the opposite ions diffuse at equal rates, this last equation merely expresses the fact that the resistance offered by the liquid to the passage of an electrolyte is the sum of the resistances offered to the passage of its ions—a result which we should naturally have expected from the general properties of electrolytic solutions.

Thus, on the osmotic pressure analogy, the force acting on one gram-molecule of hydrochloric acid is $-\frac{1}{c}\frac{dp}{dx}$; so that, if we call k the resistance offered when the velocity is unity, the average velocity will be $-\frac{1}{ck}\frac{dp}{dx}$, and the number of gram-molecules crossing a section of the cylinder in one second will be

$$dN = -\frac{1}{ck}\frac{dp}{dx}\cdot cq\,dt = -\frac{1}{k}q\frac{dp}{dx}dt.$$

Now the osmotic pressure of an electrolyte with two ions is double the normal value, so that

$$p = 2cRT,$$

and we get

$$dN = -\frac{2RT}{k}q\frac{dc}{dx}dt.$$

The resistances to hydrogen and chlorine moving with unit velocity are $1/U$ and $1/V$ respectively, so that the resistance to hydrochloric acid is

$$k = \frac{1}{U} + \frac{1}{V} = \frac{U+V}{UV},$$

and we get the same equation as Nernst—

$$dN = -\frac{2UV}{U+V} RT q \frac{dc}{dx} dt.$$

From the general theory of diffusion we may take the quantity of substance diffusing through unit area in one second to be proportional to the gradient of concentration, so that the quantity crossing an area q in a time dt is

$$dN = -Dq \frac{dc}{dx} dt$$

where D is a constant.

By comparing this with our last equation, we see that, for electrolytes, the diffusion constant is given by the expression

$$D = \frac{2UV}{U+V} RT.$$

T is the absolute temperature, R the gas constant corresponding to one gram-equivalent of substance (viz. 1·974 calories per degree or $8·29 \times 10^7$ ergs per degree), so that it only remains to calculate U and V, the velocities with which the ions move under the action of unit force.

We have already seen that the charge of electricity carried by one gram-equivalent of a kation is $+1/\eta$, and the charge on one gram-equivalent of an anion is $-1/\eta$, where η represents the electro-chemical equivalent of hydrogen. The quantity of electricity associated with one gram-equivalent of any ion is therefore $1/·00010352 = 9653$ electromagnetic units. If the potential gradient is one volt (10^8 C.G.S. units) per centimetre, the force acting on this gram-equivalent will be $9{,}653 \times 10^8$ dynes. This, in dilute solution, gives the ion its specific velocity, say u. Thus the force required to give the ion unit velocity is

$$P_A = \frac{9·653 \times 10^{11}}{u} \text{ dynes} = \frac{9·84 \times 10^5}{u} \text{ kilograms weight.}$$

If the ion have an equivalent weight A, the force producing unit velocity when acting on one gram is $P_1 = 9·84 \times \frac{10^5}{Au}$ kilograms weight. Thus, in order to drive one gram of potassium ions with a velocity of one centimetre per second through a very dilute water solution, we must exert a force equal to the weight of 38,000,000 kilograms. The table gives other examples.[1]

—	Kilograms Weight		—	Kilograms Weight	
	P_A	P_1		P_A	P_1
K . .	15×10^8	38×10^6	Cl . .	14×10^8	40×10^6
Na . .	22 „	95 „	I . .	14 „	11 „
Li . .	27 „	390 „	NO_3 . .	15 „	25 „
NH_4 . .	15 „	83 „	OH . .	5·4 „	32 „
H . .	3·1 „	310 „	$C_2H_3O_2$.	27 „	46 „
Ag . .	17 „	16 „	$C_3H_5O_2$.	30 „	41 „

[1] Kohlrausch, *Wied. Ann.* 1893, vol. l. p. 385.

Since the ions move with uniform velocity, the frictional forces brought into play must be equal and opposite to the driving forces acting, and therefore these numbers also represent the ionic friction coefficients in very dilute solution at 18° C.

Let us now return to the consideration of the velocity. We have seen that the force acting on one gram-equivalent of an ion, when the potential gradient is one volt per centimetre, is $9{,}653 \times 10^8$ dynes, and that, in dilute solution, this gives to the ion its specific velocity u. The velocity it would attain under unit force will therefore be

$$U = \frac{u}{9653} \times 10^{-8} \text{ cms. per second.}$$

In the case of hydrochloric acid, for example, the specific velocity of the hydrogen is 0·0032, and that of the chlorine 0·00069 cm. per second.

$$\therefore U = 3{\cdot}32 \times 10^{-15}, \text{ and } V = 7{\cdot}15 \times 10^{-16} \text{ cms. per second.}$$

$$\therefore D = \frac{2UV}{U+V} RT = 2{\cdot}49$$

the velocities, for convenience, being reckoned in centimetres per day.

By experiments on diffusion this constant D can be found experimentally,[1] and the agreement between theory and Scheffer's observations is shown by the table.

Substance	D observed	D calculated
Hydrochloric acid, HCl	2·30	2·49
Nitric acid, HNO_3	2·22	2·27
Potash, KOH	1·85	2·10
Soda, NaOH	1·40	1·45
Sodium chloride, NaCl	1·11	1·12
Sodium nitrate, $NaNO_3$	1·03	1·06
Sodium formate, NaCOOH	0·95	0·95
Sodium acetate, $NaCO_2CH_3$	0·78	0·79
Ammonium chloride, NH_4Cl	1·33	1·44
Potassium nitrate, KNO_3	1·30	1·38

The theoretical numbers are slightly increased by the assumption that the ionisation of the solutions is complete, which is not accurately the case. This correction, then, would make the agreement still better.

The possibility of thus calculating the diffusion constant must be regarded as very strong evidence in favour of the soundness of the analogy underlying the investigation.

Further developments for the cases of other solvents and of mixed electrolytes have been traced by Arrhenius,[2] who shows, for example, that the rate at which hydrochloric acid diffuses will be increased by the presence of one of its salts. This is confirmed experimentally. Thus, when 1·04 normal HCl diffuses into 0·1 NaCl, D is calculated as 2·43 and observed as 2·50 ; and when the NaCl solution is 0·67 normal, calculation gives 3·58 and observation 3·51.

Contact Difference of Potential.—As we have seen above, when a solution is placed in contact with water, the water will take a positive or

[1] Account in *Solution and Electrolysis*, p. 49.
[2] *Zeits. physikal. Chem.* 1892, vol. x. p. 51.

negative potential with regard to the solution, according as the kation or the anion has the greater specific velocity and, therefore, the greater initial rate of diffusion. This idea can be developed to explain the difference of potential at the surface of contact of two solutions or of a solution and a metal.

Taking the equation which expresses the relation that, when a steady state is reached, the ions migrate at equal rates, viz.—

$$\mathrm{U}\,q\,dt\left(\frac{dp}{dx}+c\frac{d\mathrm{P}}{dx}\right)=\mathrm{V}\,q\,dt\left(\frac{dp}{dx}-c\frac{d\mathrm{P}}{dx}\right)$$

we get

$$\frac{d\mathrm{P}}{dx}=\frac{1}{c}\,\frac{\mathrm{V}-\mathrm{U}}{\mathrm{V}+\mathrm{U}}\cdot\frac{dp}{dx};$$

or, since for dilute solutions $p=c\mathrm{RT}$,

$$\frac{d\mathrm{P}}{dx}=\frac{\mathrm{RT}}{p}\cdot\frac{\mathrm{V}-\mathrm{U}}{\mathrm{V}+\mathrm{U}}\,\frac{dp}{dx}$$

which gives on integration

$$\mathrm{P}_2-\mathrm{P}_1=\mathrm{RT}\frac{\mathrm{V}-\mathrm{U}}{\mathrm{V}+\mathrm{U}}\,\log_e\frac{p_2}{p_1}.$$

If we have absolutely pure water in contact with a solution, p_1 is zero, and the difference of potential apparently becomes infinite. Absolutely pure water cannot be obtained, and the table of Nernst's experimental results, given on p. 242, shows too small a range of concentrations to fairly test this equation. Nevertheless, cases will be described later in which high potential-differences were observed when the concentration of the ions on one side was made very small.

When the solutions of two different electrolytes are placed in contact, similar things occur. Thus (Nernst) let us suppose that we have a solution of hydrochloric acid in contact with one of lithium bromide. On the one hand more hydrogen ions than chlorine ions will diffuse from the acid solution into the other, and therefore the salt solution will receive a positive charge. On the other hand, more bromine ions than lithium ions will diffuse from the salt solution into the acid, and thus the potential difference will be increased.

When a metal dissolves in a solution, Nernst traces an analogy with the evaporation of a liquid. He ascribes to each metal a 'solution-pressure' with regard to water, depending only on the temperature, which tends to drive the metal into solution in the form of positively charged ions. But this process will electrify the solution positively, and leave the metal negatively charged. Electric forces will therefore be set up, which oppose the further solution of the metal, and seek to drive back to it the ions already in solution. The electrostatic capacities of the ions are very great, and hence equilibrium may be reached long before a weighable quantity has been dissolved.

As the quantity of ions in solution increases, we may get equilibrium set up, the solution pressure being balanced by the osmotic pressure of the dissolved ions and the electrostatic forces of their charges. This happens, for example, when silver is dipped into a solution of sodium chloride. If, however, the solution pressure is very great, the electric forces may reach such an amount that positive ions must be driven out of the solution. Such cases occur when hydrogen is evolved from acids or

one metal precipitated from its solution by another. In each case an electrically equivalent amount of the metal is dissolved.

When hydrogen is evolved, it is first dissolved by the metal, from which it separates in an electrically neutral form as soon as its concentration is high enough to give it a vapour pressure exceeding one atmosphere. The process can be arrested by the application of an atmospheric pressure sufficiently great, and this gives a measure of the solution pressure of the metal used. Experiments are difficult, but Beketoff [1] and Brunner [2] have shown that hydrogen at a high pressure can precipitate silver, platinum, and palladium; Cailletet [3] arrested its evolution from zinc and sulphuric acid, while Nernst and Tammann [4] have examined the action of other metals.

The electromotive force developed at the contact of a metal and a solution of one of its salts has been deduced by Nernst by considering the work done when one unit of electricity passes,[5] but it seems that the same result can be obtained from the equation giving the potential difference between the solutions of an electrolyte of different concentration, which we have already developed in the form

$$P_2 - P_1 = RT\frac{V-U}{V+U}\, log_e \frac{p_2}{p_1}.$$

If we suppose that in the case of a metal we are concerned with one ion only—the positive one—we can put $V = 0$, since no negative ions enter or leave the metal, and the equation becomes

$$E = -RT\, log_e \frac{p_2}{p_1}$$

where p_2 denotes something corresponding to the osmotic pressure of the kations in the substance of the electrode, which gives its solution pressure P. Thus, neglecting the negative sign, we get

$$E = RT\, log_e \frac{P}{p}$$

p denoting the osmotic pressure of the ions of the metal in the solution.

In a simple galvanic cell of any ordinary form there are two metals, say zinc and copper, in contact with the same solution of electrolyte. The equation then becomes

$$E = RT\left(log_e \frac{P_1}{p_1} - log_e \frac{P_2}{p_2}\right)$$

where P_1 and p_1 refer to the zinc, and P_2 and p_2 to the copper. In two-fluid cells, such as the Daniell, since the electromotive forces at the electrodes are much greater than at the contact of the liquids, the same equation may still be applied.

Galvanic cells can be constructed with two electrodes of the same metal placed in solutions of different substances, or even of the same substance at different concentrations. In this case, since the unknown solution pressure of the metal is the same at the opposite electrodes, we can calculate the total electromotive force of the cell.

[1] *Compt. Rend.* vol. xlviii. p. 442 (1859).
[2] *Pogg. Ann.* vol. cxxii. p. 153 (1864).
[3] *Compt. Rend.* vol. lxviii. p. 395 (1869).
[4] *Zeits. physikal. Chem.* vol. ix. p. 1 (1892).
[5] *Zeits. physikal. Chem.* vol. iv. p. 148 (1889).

Thus, taking a combination arranged according to the scheme

$$Ag \mid 0{\cdot}1\ AgNO_3 \mid 0{\cdot}01\ AgNO_3 \mid Ag$$

in which silver electrodes are placed, one in decinormal and one in centinormal solutions of silver nitrate, we get from the sum of the electromotive forces of its various junctions

$$E = RT\left(log_e \frac{P}{p_1} + \frac{V-U}{V+U}\, log_e \frac{p_1}{p_2} - log_e \frac{P}{p_2}\right)$$
$$= RT\, \frac{2U}{V+U}\, log_e \frac{p_2}{p_1}$$

where p_1 and p_2 denote the osmotic pressures of the silver ions in decinormal and centinormal solutions of silver nitrate respectively.

In the scheme

$$Hg \mid Hg_2Cl_2 \mid 0{\cdot}1\ HCl \mid 0{\cdot}01\ HCl \mid Hg_2Cl_2 \mid Hg$$

we have the first and the last contact identical, so that we may consider the 'depolariser,' mercurous chloride, as the electrode, and thus get a cell whose action depends on the negative chlorine ions. Its electromotive force will be

$$E = RT\, \frac{2V}{U+V}\, log \frac{p_1}{p}.$$

By this method the following table was constructed by Nernst,[1] giving a comparison between the observed and calculated values of the electromotive force of concentration cells. C_1 and C_2 denote the concentration of the two solutions in gram-equivalents per litre.

Electrolyte	C_1	C_2	E in volts (observed)	E in volts (calculated)
HCl . . .	0·105	0·0180	0·0710	0·0717
,, . . .	0·1	0·01	0·0926	0·0939
HBr . . .	0·126	0·0132	0·0932	0·0917
KCl . . .	0·125	0·0125	0·0532	0·0542
NaCl . . .	0·125	0·0125	0·0402	0·0408
LiCl . . .	0·1	0·01	0·0354	0·0336
NH_4Cl . .	0·1	0·01	0·0546	0·0531
NaBr . .	0·125	0·0125	0·0417	0·0404
$NaO_2C_2H_3$ . .	0·125	0·0125	0·066	0·0604
NaOH . .	0·235	0·030	0·0178	0·0183
NH_4OH . .	0·305	0·032	0·024	0·0188
KOH . . .	0·1	0·01	0·0348	0·0298

The equations indicate that, in cells with both electrodes of the same metal, the electromotive force will be greater if the concentration of the ions of the metal in the solution round one electrode is made very small. This can easily be done by placing the electrode in a solution which pre-

[1] *Zeits. physikal. Chem.* vol. iv. p. 161 (1889).

cipitates the metal. Thus Ostwald[1] found that the electromotive force of the cell

$$Ag \mid 0{\cdot}1\ AgNO_3 \mid 1{\cdot}0\ KCl \mid AgCl \mid Ag$$ [2]

was 0·51 volt. Here the osmotic pressure of the silver ions in the solution of potassium chloride is very small to begin with, and is still further reduced because the solubility of the silver chloride is lowered by the presence of chlorine ions. The pressure can be calculated, and an application of Nernst's formula leads to a theoretical value for the electromotive force of 0·52 volt—a remarkable agreement with the observed value.

Other similar cells, giving high electromotive forces with identical electrodes, were examined by Ostwald.

					Volt.
1.	Silver nitrate	(0·1)	against	silver chloride in potassium chloride	0·51
2.	"	"	"	ammonia	0·54
3.	"	"	"	silver bromide in potassium bromide	0·64
4.	"	"	"	sodium thiosulphate	0·84
5.	"	"	"	silver iodide in potassium iodide	0·91
6.	"	"	"	potassium cyanide	1·31
7.	"	"	"	sodium sulphide	1·36

Comparisons of other cells, in all cases showing an agreement between the observed values and those calculated on the analogy of Nernst and Planck, will be found in the second volume of Ostwald's 'Lehrbuch,' pp. 848, 850.

The number of silver ions can also be reduced by adding some substance which, by combining with them, removes them from solution. This is shown by the fact that cells Nos. 2, 4, and 6 in the above list have, like the others, high electromotive forces.

Other metals have been used as electrodes by Zengelis,[3] who showed that, in many cases, the electromotive forces of cells whose electrodes were copper, lead, nickel, or cobalt were greater the more the concentration of the ions round one electrode was depressed by the addition of a salt.

Hittorf[4] has even shown that the effect of a cyanide round a copper electrode is so great that copper becomes electropositive towards zinc. Thus the cell

$$Cu \mid KCN \mid K_2SO_4 \mid ZnSO_4 \mid Zn$$

furnishes a current which carries copper into solution and deposits zinc. In a similar way, silver could be made positive towards cadmium.

If we know the concentration of the ions round one electrode, it is possible to calculate them round the other from observations on the electromotive force, and this has been done by Behrend.[5]

The same ideas have been applied by Le Blanc[6] to the study of gal-

[1] *Lehrbuch*, 2nd ed. vol. ii. p. 882.

[2] In order to prevent the formation of a precipitate an indifferent substance, *e.g.* KNO_3, is interposed between the $AgNO_3$ and the KCl.

[3] *Zeits. physikal. Chem.* vol. xii. p. 298 (1893).

[4] *Zeits. physikal. Chem.* vol. x. p. 592 (1892).

[5] *Zeits. physikal. Chem.* vol. xi. p. 466 (1893).

[6] *Zeits. physikal. Chem.* vol. viii. p. 299; vol. xii. 333; vol. xiii. 163 (1891–94).

vanic polarisation. He finds that, at the decomposition point in a solution from which a metal is deposited at the kathode, the electromotive force of polarisation at this electrode is equal to the electrolytic solution pressure of the metal in the solution, and is independent of the nature of the electrode, provided it is not attacked. The numerous apparent exceptions to this rule are referred to secondary effects, such as the development of gases at the electrodes, which cause the electromotive force necessary for their liberation to depend on the nature and condition of the electrode. This, for example, makes the decomposition limit of water rise to about 1·6 volt; but when these effects are eliminated, it is found that the true value comes out as 1·03 volt. Now 1·03 volt is the maximum electromotive force of the oxy-hydrogen gas battery; and thus the decomposition of water is a reversible process at 1·03 volt.

Freudenberg[1] has applied the theory to the electrolytic separation of metals, and finds that metals are separated from a solution, through which a constantly increasing current flows, in the reverse order of their 'decomposition pressures.' They can often be thus separated for quantitative chemical analysis. The influence of the solvent on the solution pressure of metals has been investigated by H. C. Jones,[2] who examined cells whose electrodes were silver in solutions of silver nitrate of equal strength, the solvent round one electrode being water, and round the other ethyl alcohol, methyl alcohol, or acetone. In all cases the water solution was negative to the other. The ionisation of the salt in ethyl alchohol being known, the ratio of the solution pressures can, in this case, be calculated, and comes out 0·024.

Much discussion has taken place about the exact significance of the 'solution pressure' of a metal—the property represented by P in Nernst's equations. Following Nernst, Ostwald considers that P is a function of the metal and temperature only, and consequently independent of the nature of the negative iron. Measurements of the potential differences at single reversible junctions—*i.e.* when the kation is of the same metal as the electrode—have been made by Le Blanc[3] and Neumann.[4] The latter measured the electromotive forces of cells made up with the junction in question at one electrode, and mercury in a normal potassium chloride solution with an excess of calomel at the other. The normal mercury calomel electrode has a potential difference of 0·560 volt, and thus the value of the other contact could be found, the potential difference between the liquids being assumed to be small. Neumann found that at great dilution the potential difference was in general independent of the anion; but Paschen, Bancroft, and other observers, working with metals in solutions not of their own salts, which there is reason to suppose form limiting cases of the reversible electrodes and are subject to the same laws, have found that the potential difference does, when the metal is copper, platinum or mercury, depend on the anion. Many experiments on cells containing non-reversible electrodes have been made to determine the influence of the nature of the ions and of concentration. Among these experiments we may mention those of Paschen,[5] Ostwald,[6] Oberbeck and

[1] *Zeits. physikal. Chem.* vol. xii. p. 97 (1893).
[2] *Zeits. physikal. Chem.* vol. xiv. p. 346 (1894).
[3] *Zeits. physikal. Chem.* 1893, vol. xii. p. 345.
[4] *Zeits. physikal. Chem.* 1894, vol. xiv. p. 225.
[5] *Wied. Ann.* 1891, vol. xliii. p. 590.
[6] *Zeits. physikal. Chem.* 1887, vol. i. p. 583.

Edler,[1] Bancroft,[2] and A. E. Taylor.[3] Taylor finds reason to suggest that the differences found by some of the observers on changing the anion may be due to large potential differences at the surface of contact of the two liquids in the cells. He finds that such differences arise in cases where there is a tendency to form complex salts. Moreover, it has been found by Gouy,[4] Rothmund,[5] and Luggin[6] that the maximum surface tension of mercury is not the same in all solutions, as Lippmann's law supposes, but varies in cases where complex salts might be formed. Now the values taken for the potential difference at a contact between mercury and solution depend on this result, and so an error is introduced into many of the observations which depend on the subtraction of this potential difference from the total electromotive force of a cell. Such considerations may possibly explain exceptions to the rule that the potential difference between a metal and an electrolyte is independent of the nature of the anion. More experiments on the subject, particularly with reversible electrodes, would be of great value.

In a general review of the results of this theory of the migration of the ions, the agreement between calculation and observation is most remarkable. The experimental measurements of the absolute velocities of various ions, which have been described, fully confirm the general truth of the theory, and leave no doubt that the values calculated from the conductivities and migration constants give the real average speeds with which the ions travel.

The ability of Kohlrausch's theory to represent the facts being thus established, it must follow that, in dilute solutions, the motion of one ion is independent of the nature of the other ion present. This suggests that the ions are free from each other for, at any rate, the greater part of their time, and this idea is, as we have seen, confirmed by the fact that the conductivity of a dilute solution is proportional to the concentration, whereas, if the ion were free only at the instants of collision between dissolved molecules, it would vary as some higher power of the concentration.

Further evidence, pointing in the same direction, is furnished by the general success of Nernst and Planck's theory of the diffusion of electrolytes, and of the contact difference of potential between solutions. The numerical deductions from this theory, which agree in general with the results of experiment, involve (i.) the specific ionic velocities, as determined by Kohlrausch, and (ii.) the freedom of the opposite ions to migrate independently of each other until the electrostatic forces prevent further separation. Thus we seem obliged to accept the idea, originally suggested and strongly supported by other phenomena outside the scope of this section of the Report, that the ions not only enjoy perfect freedom of interchange, as Ohm's law demands, but are actually dissociated from each other for, at any rate, the greater part of their existence. It must be particularly noticed that this freedom from each other does not at all prevent the ions from forming chemical combinations with the solvent

[1] *Wied. Ann.* 1891, vol. xlii. p. 209.
[2] *Zeits. physikal. Chem.* 1893, vol. xii. p. 289; *Physical Review*, 1896, vol. iii. p. 250.
[3] *Journal Physical Chemistry*, 1896, vol. i. pp. 1, 81.
[4] *Compt. Rend.* 1892, vol. cxiv. pp. 22, 211, 657.
[5] *Zeits. physikal. Chem.* 1894, vol. xv. p. 1.
[6] *Zeits. physikal. Chem.* 1895, vol. xvi. p. 667.

molecules. Neither does it throw any light on the fundamental nature of solution. It has been very generally assumed that the dissociation theory of electrolytes was necessarily bound up with a view of solution which considers the dissolved matter to be in a state dynamically similar to that of a gas, and to produce osmotic pressure by the impacts of its molecules, just as a gas produces pressure on the walls of its containing vessel.

Now Poynting[1] has shown that the phenomena of osmotic pressure can, on certain not improbable assumptions, be completely represented by the hypothesis that chemical union occurs between the solvent and the dissolved matter. In the present state of our knowledge the dissociation theory of electrolytes seems perfectly compatible with such an explanation.[2] All that follows from the facts is the essential freedom of the ions from each other. Whatever be the cause of osmotic pressure, it certainly depends, to a first approximation, at all events, on the number of dissolved molecules, and not on their nature, and thus, whether it be due to impact or to chemical union, it will have an abnormally great value when, as in the case of electrolytes, the number of effective molecules is increased by dissociation.

Again, the theory does not forbid the assumption that complex molecular aggregates, formed of two or more solute molecules, may exist, especially in concentrated solutions, as well as dissociated ions. Such molecules would be electrolytically inactive, unless an odd ion was linked to them. They would also, as has been suggested by Wildermann and others, explain a lowering of the freezing point less than that calculated from the conductivity.

It has been found that the specific resistance of many liquids, including water (*i.e.* a dilute solution of electrolytes), increases when the electrodes are brought within a certain critical distance of each other.[3] Similar phenomena have been observed in the case of gases, through which an electric discharge was passing, by Lord Kelvin, Baille, and Peace,[4] and this has been explained by J. J. Thomson on the hypothesis that a complete chain-like structure is necessary for electrolytic conduction, which cannot occur unless there is room for such a chain to form. It is possible that the same explanation may hold good for liquids, the necessary electrolytic unit being a complex structure formed of a dissociated ion and several solvent molecules. From what has been said, it will be seen that there is nothing inconsistent with this idea in the dissociation theory.

To sum up the results of this section, we may say that, whatever may be the ultimate nature of solution, it seems certain that the electrolytic ions migrate in accordance with Kohlrausch's theory, and, in a homogeneous solution, are free to travel independently of each other through the liquid.

[1] *Phil. Mag.* 1896, vol. xlii. p. 289.
[2] See letters in *Nature*, 1896, vol. liv. p. 571; vol. lv. pp. 33, 78, and 150.
[3] Koller, *Wien. Ber.* 1889, vol. 98, ii. p. 201.
[4] See J. J. Thomson's *Recent Researches in Electricity*, p. 72.

The Historical Development of Abelian Functions up to the time of Riemann. By HARRIS HANCOCK.

[Ordered by the General Committee to be printed *in extenso* among the Reports.]

(1) IN 1846, R. Leslie Ellis[1] presented to the British Association a 'Report on the Recent Progress of Analysis (Theory of the Comparison of Transcendents).' At the beginning of this memoir he says: 'The province of analysis, to which the theory of elliptic functions belongs, has within the last twenty years assumed a new aspect; in no subject, I think, has our knowledge advanced so far beyond the limits to which it was not long since confined.' 'This circumstance,' he continues, 'would give a particular interest to a history of the recent progress of the subject, even did it now appear to have reached its full development. But on the contrary, there is now more hope of further progress than at the commencement of the period of which I have been speaking.'

These statements appear more emphatic when we consider that after the lapse of fifty years, since the publication of Ellis's report to the present time, the same remarks are literally true, and when at the end of this period we find that there is more hope for the future progress of analysis, the theory of functions, than there has ever been before.

So great has been the growth of this science, extending on the one hand, and with a broadening influence, far into the realms of almost every branch of mathematical study, and on the other hand so comprehensive and varied in character is its application to physical problems, that the development of Ellis's work must be divided into many parts.

(2) The present report which the author has the honour of submitting to the Association is intended as a brief account of that part of the work already begun by Ellis which treats of the developments of the Abelian (including the hyperelliptic) functions. It is also found that the development of these functions has been so rapid and so extended that an adequate account of it would require much more space than can be given here. The author has consequently decided to make this statement for the period up to the time of Riemann. With Riemann, Weierstrass, Clebsch and Gordan, Cayley and others, the subject takes directions so essentially different that separate accounts along these different lines seem very desirable.

Much regarding the history of the general theory of functions may be found in Forsyth, 'Theory of Functions'; Harkness and Morley, 'A Treatise of the Theory of Functions'; Casorati, 'Teorica delle funzioni di variabili complesse'; Brill and Nöther, 'Die Entwicklung der algebraischen Functionen in älterer und neuerer Zeit' (see 'Jahresbericht der deutschen Mathematiker-Vereinigung,' 1894, bd. iii.). Fruitful sources for researches regarding the elliptic functions are Königsberger, 'Zur Geschichte der Theorie der elliptischen Transcendenten in den Jahren 1826–29,' Leipzig, 1879; short notices about the *first discovery of elliptic functions* are given by Gauss, 'Werke,' iii. p. 491; 'Correspondance mathématique entre Legendre et Jacobi' (Crelle's Journal, bd. lxxx. p. 205); and especially good is the account given by Enneper, 'Elliptische Functionen: Theorie und Geschichte,' Halle, 1890.

These works give more or less extended accounts of the subject under

[1] Ellis, *Report of the British Association for the Advancement of Science,* 1846, p. 34. We shall hereafter use the word 'Ellis' in referring to this paper.

consideration; other sources of information will be cited in their proper places.

(3) A good account (especially from the German standpoint) is given of the early development of the theory of functions by Brill and Nöther (*loc. cit.*). I shall here consider very briefly only such parts of the theory of elliptic functions that have a direct bearing upon this report, omitting as far as possible what has already been given by Ellis.

(4) The contributions towards the advancement of the elliptic functions by Tschirnhaus (1683–1700), the Bernoullis (1690–1730), Fagnano ('Produzioni Matematiche,' Pesaro, 1750) are discussed by Enneper ('Elliptische Functionen').

Two works which must have exercised great influence upon subsequent writers are Maclaurin, 'A Treatise on Fluxions,' Edinb. 1742, and d'Alembert, 'Recherches sur le calcul intégral' ('Histoire de l'Acad. de Berlin,' 1746, pp. 182–224).

(5) Euler extended and systematised the work that Fagnano had begun. It was known that the expressions for $\sin(\alpha+\beta)$, $\sin(\alpha-\beta)$, etc., gave a means of adding or subtracting the arcs of circles, and that between the limits of two integrals that express lengths of arc of a lemniscate an algebraical relation exists, so that the arc of a lemniscate, although a transcendent of higher order, may be doubled or halved just as the arc of a circle by means of geometric construction.

It was natural to inquire if the ellipse, hyperbola, etc., did not have similar properties; investigating such questions, Euler made the remarkable discovery of the addition-theorem of elliptic integrals (*cf.* 'Nov. Comm.' Petrop. vi. pp. 58–84, 1761; vii. p. 3; vii. p. 83).

Euler showed that if

$$\int_0^x \frac{d\xi}{\sqrt{\phi(\xi)}}+\int_0^y \frac{d\xi}{\sqrt{\phi(\xi)}}=\int^a \frac{d\xi}{\sqrt{\phi(\xi)}},$$

where $\phi(\xi)$ is a rational integral function of the fourth degree in ξ, there exists between the upper limits x, y, and a of the integrals an algebraic relation which is the addition-theorem of the arcs of an ellipse and is the algebraic solution of the differential equation[1]

$$\frac{d\xi}{\sqrt{\phi(\xi)}}+\frac{d\eta}{\sqrt{\varphi(\eta)}}=0.$$

Euler stated that the above results were obtained, not by any regular method, but *potius tentando, vel divinando*, and suggested that mathematicians seek a direct proof. The numerous discoveries of Euler are systematised in his work, 'Institutiones calculi integralis.'

The fourth volume (p. 446) contains an extension of the addition-theorem to integrals of the second and third kinds, as they were subsequently classified and named by Legendre.

In each case geometrical application of the formulæ are made for the comparison of elliptic arcs.

(6) The addition-theorem for elliptic integrals gave a similar meaning in higher analysis to the elliptic functions as the cyclometric and logarithmic functions had had for a long time. See Enneper ('Ellipt. Funct.,' p. 541 *et seq.*) regarding the position occupied by Euler in the development of the elliptic functions, and for a statement regarding Legendre's work in

[1] Euler, *Nov. Comm.* vol. x. pp. 3–50.

this branch of mathematics *confer* Dirichlet's 'Gedächtnissrede auf Jacobi' (Jacobi's 'Werke,' vol. i. p. 9).

(7) The suggestion made by Euler that one should find a direct method of integrating the differential equation proposed by him (art. 5) was carried out by Lagrange, who by direct methods integrated this equation, and in a manner which elicited the great admiration of Euler. (See 'Miscell. Taurin.,' iv. 1768; or Serret's 'Œuvres de Lagrange,' vol. ii. p. 533.)

(8) The consideration of relations between integrals that have different moduli gave rise to a theorem due to Landen (and proved somewhat differently by Lagrange), in accordance with which an elliptic integral may be transformed into another integral of the same kind by means of algebraic transformations. Landen ('Phil. Trans.,' 1775, p. 285; or 'Mathematical Memoirs,' by John Landen, London, vol. i. 1780, p. 33) proves that in general the hyperbola may be rectified by means of two ellipses, with the addition of an algebraic quantity.[1]

The germ of the general theory of transformation is contained in this theorem, as has been observed by Legendre.[2]

By means of algebraic tranformations Landen was able to reduce elliptic integrals of the first kind into forms that had the same modulus, and showed that an elliptic integral of the first kind could be transformed into an elliptic integral of the first kind with smaller modulus, or into an integral of the first kind with smaller amplitude and greater modulus.

Lagrange[3] showed that the integration of any irrational function which contains the square root of a function ϕ may be made to depend upon the integration of a function of the form $\frac{P(x)}{\sqrt{\phi(x)}}$ where P is rational; and that if ϕ is not higher than the fourth degree in x, the integration may be reduced to that of

$$\frac{N dx}{\sqrt{(1 \pm p^2x^2)(1 \pm q^2x^2)}},$$

N denoting a rational function in x^2, and p and q constants. If the elliptic integral be reduced to this form, Lagrange showed by the introduction of a new variable that this integral may be transformed into another of similar form, but in which p and q become two new quantities p' and q', and that if p is greater than q, p' becomes greater than p and q' less than q. By the repetition of this process the factor corresponding to $1 \pm q^2x^2$ may be made as near unity as we desire, and consequently the integral may be expressed by a circular arc or logarithm; if, however, the transformations are made in the other direction, the functions corresponding to $1 \pm p^2x^2$ and $1 \pm q^2x^2$ become as near equal as we wish, and thus the elliptical integral reduces to a lower transcendent.[4]

Legendre investigated the general integral given above,

$$\int \frac{P dx}{\sqrt{\alpha + \beta x + \gamma x^2 + \delta x^3 + \epsilon x^4}},$$

[1] An interesting geometric construction of this transformation is found in a letter of Jacobi to Hermite (Jacobi's *Werke*, bd. ii. p. 118). See also a geometric proof by MacCullagh (*Trans. of the Royal Irish Academy*, vol. xvi. p. 76).

[2] See Ellis, p. 37.

[3] *Mémoire de l'Acad. de Sc.*, 1784–85; *Œuvres* ii. p. 253.

[4] Ellis, p. 44. Casorati, *Teorica delle funzioni*, &c., p. 6.

and showed that it was always possible to reduce it to one or the other of three forms essentially different.

We may mention, in passing, as being among the early English contributions to the subject memoirs by Brinkley ('Dublin Trans.' ix. p. 145, 1803) and Wallace ('Edinb. Trans.' v. p. 253). A criticism of Talbot's 'Researches on the Integral Calculus' ('Phil. Trans.' 1836, p. 177, and 1838, p. 1) is given by Ellis, p. 41.

(9) The theory of the elliptic functions, as Abel and Jacobi[1] found it in 1827, offered many highly enigmatical phenomena, which could not be explained by the principles that were at that time in vogue. For example, the degree of the equation which is found by means of Euler's theorem, and upon whose solution depends the division of the elliptic integral, was not, as in the analogous question of the division of the circle, equal to the number of the parts, but to the square of this number. It was easy to see the meaning of the real roots, whose number agrees with the number we have in the division of the circle; however, the number of imaginary roots must have seemed without explanation (Dirichlet, 'Gedächtnissrede,' p. 9).

We shall next consider the *inverse functions* of the integrals which we have been treating. With Jacobi[2] we begin with the simple algebraic integral

$$u=\int_0^x\frac{dx}{\sqrt{1-x^2}}=\sin^{-1}x.$$

In this expression we may either consider u as a function of the upper limit x, or inversely, the upper limit x as a function of u. In the first case, when $u=\sin^{-1}x$, it is not possible to express u in the form of a power series which is convergent for every value of x; and for a given value of x, u is not determinate, but has an infinite number of values, differing by multiples of 2π. But when we regard the upper limit x as a function of u, and write $x=\sin u$, then x may be expressed as a series which is convergent for all values, real and imaginary, of u; and when u is given a definite value, then x also has a definite value, and x considered as a function of u enjoys all the properties of a rational function.

The next more general algebraic integral is the elliptic integral

$$u=\int_0^x\frac{dx}{\sqrt{(1-x^2)\ (1-\kappa^2x^2)}}=\Pi(x).$$

As above, $u=\Pi(x)$ cannot be expressed by a series that is always convergent; and for a given value of x the variable u has not a definite value, but a double infinity of values, differing by multiples of the periods of elliptic functions (see next article).

The innate property of this integral could not be recognised if we considered the transcendent x alone; but we have to regard the upper

[1] Their first writings on this subject are: Abel, Crelle, bd. ii. September 1827; Jacobi, two letters to Schumacher dated June 13 and August 2, 1827, in the *Astronomische Nachrichten*, No. 123, vol. vi.

[2] Jacobi, *Considerationes generales de transcendentibus Abelianis* (*Werke*, bd. ii. p. 8).

limit x as a function of u, and with Legendre we write $x=\sin\phi$, so that the integral above becomes

$$u=\int_0^\phi \frac{d\phi}{\sqrt{1-\kappa^2\sin^2\phi}}.$$

We consider ϕ as a function of u, and write ϕ=amplitude of $u=\text{am}(u)$, so that $x=\sin\text{am}\,(u)=\text{sn}\,u$.

The function $x=\text{sn}\,u$ enjoys all the properties of a rational *fractional* function, and, as is shown later in connection with the θ-function, the numerator and denominator of this fraction may be developed in rapidly convergent series for all real or imaginary values of u. Hence the elliptic function $x=\text{sn}\,u$ has one, and only one, definite value, corresponding to a given value of u.

(10) *Periods of the inverse functions.*—Abel and Jacobi recognised that the elliptic functions have at the same time the nature of circular functions and of exponential functions in that they are periodic for both real and imaginary values of the arguments. They saw that the function $x=\text{sn}\,u$, for example, remained unaltered when u is changed into $u+4\text{K}$ or into $u+2\text{K}'\sqrt{-1}$, where K and K′ are definite constants.

Jacobi often repeated that the introduction of the imaginary was a complete solution of all the enigmas that had previously beset this subject.[1]

The introduction of the imaginary and the necessity of treating the limit as a function of the integral were two great advances made by Jacobi and Abel.

(11) Abel's investigations took different directions from those of Jacobi. Abel devoted himself to problems that have to do with the multiplication and division of elliptic integrals, their double periodicity, and their definition by infinite products. By the help of the principle of double periodicity he penetrated deeply into the nature of the roots of the equation upon which the division depends, and made the unexpected discovery that the general division of the elliptic integral with arbitrary limit may be performed algebraically (*i.e.* through the extraction of roots) as soon as the special division of the so-called *complete* integrals is presupposed performed.

The simplest case of this special division is for the modulus to which the lemniscate corresponds; and Abel shows that the division of the entire lemniscate is completely analogous to that of the circle, and may be performed by geometric construction in the same cases as the circle admits. The solution of the circle had been solved some twenty-five years before by Gauss. The admirers of Gauss with Dirichlet, from whom the above extracts have been made (*loc. cit.* p. 11), contend, from certain remarks (among others) made by Gauss in connection with the division of the circle and the lemniscate, that the principle of double periodicity was also known to Gauss. Some persons might, however, insist that Gauss too was beset by some of the enigmas above referred to, and that it was more likely that Gauss omitted to mention these dilemmas than to keep silent about the remarkable doubly periodic property of the functions that are connected with the lemniscate. In this connection Enneper ('Elliptische Functionen,' p. 7) says that it is to be regretted that Gauss did not communicate his remarkable discoveries to his contemporaries and invite their co-operation.

[1] See Dirichlet, *Gedächtnissrede auf Jacobi* (Jacobi's *Werke*, i. 10).

Another important discovery is due to Abel's investigations: when the multiplier became infinitely large in the formulæ through which he represented the elliptic functions of a multiple argument by means of functions of the simple argument, he obtained remarkable expressions for the elliptic functions in form of infinite series that are expressed as quotients of infinite products.[1]

Jacobi, contemporaneously with Abel, was occupied in another part of the theory of elliptic functions, and with equally as great success. A fortunate induction of considering the transformation and the multiplication from a common point of view, and the last as a special case of the first, led him to the conjecture that rational functions of any degree may be used to transform an elliptic integral into an integral of the same form. This conjecture was at once confirmed, since the number of constants which may be arbitrarily disposed of for any degree is sufficient to satisfy all conditions in order that the form of the transformed integral may agree with the original (*cf.* Dirichlet, *loc. cit.* p. 12).

Jacobi also showed how the elliptic functions may be expressed in the form of infinite products, which may be represented by trigonometric series, and he further used the infinite series to express the square and product of these functions. These results, with the general theory of transformation, are systematised in the 'Fundamenta Nova,' Königsberg, 1827; Jacobi's 'Werke,' bd. i. p. 49; further developments in this direction are mentioned by Enneper ('Ellip. Funct.' p. 74 *et seq.*). A report of this work is given by Ellis (pp. 49–59). See also a paper by Poisson (Crelle, bd. x. p. 342).

(12). *Statement of Abel's Theorem*—We write, as above,

$$\text{(I.)} \qquad \int_0^x \frac{dx}{\sqrt{X}} = \Pi(x).$$

If in this expression $X = 1 - x^2$, and if there exists a given algebraic relation $x_1^2 + x_2^2 = 1$, then,

$$(1) \quad \Pi(x_1) + \Pi(x_2) = \text{Constant};$$

$$\textit{i.e.}\ \text{if } \sin^2\phi + \sin^2\psi = 1 \text{ then } \phi + \psi = \frac{\pi}{2}.$$

Further, if $X = (1-x^2)(1-\kappa^2 x^2)$, and if we have given the algebraic relation[2]

$$4(1-x_1^2)(1-x_2^2)(1-x_3^2) = (2 - x_1^2 - x_2^2 + x_3^2 + \kappa^2 x_1^2 x_2^2 x_3^2)^2,$$

then is

$$(2) \quad \Pi(x_1) + \Pi(x_2) + \Pi(x_3) = 0.$$

From these two examples it is seen that, although in general we cannot integrate (I.) by means of algebraic or logarithmic functions, nevertheless, we have expressions (1) and (2) for the sums of such integrals, provided the variables that occur in these integrals are connected by algebraic relations.

By Euler's theorem, any number of elliptic integrals of the first kind may

[1] See in this connection Cayley, *Liouv. Journ.* x. p. 385; also numerous papers in his collected works:—Heine (Crelle, bd. xxxiv. p. 122); Eisenstein (Crelle, bd. xxxv. p. 153; Liouville (*Liouv. Journ.* t. ii. p. 433); Lipschitz (*Acta Math.* bd. iv. p. 193); Biermann (*Theorie der analytischen Functionen*, p. 323), &c.

[2] See a paper by Boole, 'On the comparison of transcendents,' *Phil. Trans.* 1857, p. 750; and also Rowe, 'Memoir on Abel's theorem,' *Phil. Trans.* Pt. III. 1881.

be expressed by one such integral, where the upper limit of this integral is a rational function of the upper limits of the other integrals. Similar results are found for the elliptic integrals of the second and of the third kinds. For those of the second kind there enters, in addition, an algebraic function, and for those of the third kind a logarithmic algebraic function.

Abel considered the integrals of any algebraic functions, and established a theorem for the transcendents that arise from the integrals of these functions, which has for them the same meaning as Euler's theorem has for the elliptic transcendents.

The question proposed by Abel is: Suppose X in formula (I.) above is any algebraic function of x, then is it possible, taking different variables, to establish algebraic (or logarithmic) relations between integrals of the form

$$\Pi(x)=\int_0^x \frac{dx}{\sqrt{X}},$$

when the variables are connected by requisite algebraic equations; that is, can algebraic (or logarithmic) relations be found among

$$\Pi(x_1),\ \Pi(x_2),\ \ldots\ \Pi(x_n),$$

when $x_1, x_2, \ldots x_n$ are connected by algebraic equations? If such is the case, the question next arises: How many algebraic equations are necessary, and do these equations depend upon the nature of the function X?

Abel, in his celebrated paper, 'Mémoire sur une Propriété Générale d'une Classe Très-Étendue de Fonctions Transcendantes,' 'Œuvres Complètes,' t. i. p. 145 (Sylow and Lie), considered the question in a still more general form, and found that all those functions whose derivatives may be expressed through algebraic equations, in which the coefficients are rational functions of one and the same variable possess properties that are analogous to those of the elliptic functions stated above.

The results of these investigations are expressed in the following theorem, known as Abel's theorem: *If we have several functions whose derivatives may be (expressed as) the roots of one and the same algebraic equation, and all the coefficients in this algebraic equation are rational functions of one and the same variable, then it is always possible to express the sum of any number of functions which are like the first functions by means of an algebraic (and logarithmic) function, provided a certain number of algebraic relations can be established between the variables of the function in question.*[1]

The number of these relations does not depend upon the number of the

[1] Such functions are $\frac{dw_1}{dx} = \mathrm{R}\ (y_1, x_1),\ \frac{dw_2}{dx} = \mathrm{R}\ (y_2, x_2),\ \ldots\ \frac{dw_n}{dx} = \mathrm{R}\ (y_n, x_n)$, R denoting a rational function, where $x_i (i = 1, 2, \ldots n)$ are the points of intersection of two curves $\chi(x,y) = 0$ and $\theta\ (x,y) = 0$, and y_i are the corresponding values of y that are obtained from these two equations.

Now every symmetric function of the solutions common to $\chi\ (x, y) = 0$, and $\theta(x,y) = 0$ is a rational function of the coefficients of these two equations.

Hence $\sum_{\kappa=1}^{\kappa=n} \int^{x_\kappa, y_\kappa} \mathrm{R}(x,y)dx$ is an one-valued function of the coefficients of $\chi(x, y) = 0$,

functions, but only upon the nature of the particular functions that are considered.

The same theorem is still true when we suppose the functions multiplied by any rational number positive or negative.

We may therefore deduce the following theorem: We are always able to express the sum of a given number of functions, which are multiplied each by a rational number, and in which the variables are arbitrary, by a similar sum of functions, whose number is determinate, and in which the variables are algebraic functions of the given functions.

As a further consequence is the theorem that the sum of any number of integrals of the form considered may be expressed by the sum of a definite number of such integrals with (perhaps) the addition of a determinate algebraic (and logarithmic) expression, in which the variables are algebraic functions of the variables of the first integrals.

We therefore have the following result: Although in general we cannot integrate an algebraic function by means of algebraic or logarithmic functions, we may, however, obtain for the sum of a certain number of such transcendental integrals an expression which is composed of algebraic (and logarithmic) functions.

Abel considered further the smallest number p of integrals through which the sum of any number of other integrals may be expressed. This is the well-known number which denotes the *class* (*Classen-zahl*) of the connectivity of Riemann's surface $\chi(x, y)$, upon which y is an one-valued function of x, and Clebsch's *deficiency* of the algebraic curve $\chi(x, y) = 0$. (See Cayley's 'Addition to Mr. Rowe's Memoir,' *loc. cit.* p. 752.)

Jacobi ('Werke,' bd. i. p. 379) writes: 'To this theorem we prefer to give as the most beautiful monument of [Abel's] extraordinary intellect, the name *Abel's theorem*, since it bears the entire stamp of his depth of thought. We consider it the greatest mathematical discovery of our time, as it in a simple form, and without the apparatus of the calculus, gives utterance to the deepest mathematical thought.'

Legendre calls the theorem a *monumentum ære perennius* (letter to Jacobi, Jacobi's 'Werke,' bd. i. p. 376).

The theorem is contained in a paper written in the year 1825, but not published until after Abel's death: 'Sur la comparaison des fonctions transcendantes' ('Œuvres,' t. ii. p. 55). The theorem so stated in this paper is: The sum of any number of functions which have an algebraic differential may be expressed through a definite number of such functions. It is developed in the large memoir above mentioned, 'Mémoire sur une propriété, etc.,' which was presented to the French Academy, October 1826, and not published until 1841 in the 'Mémoires des Savants Étrangers,' t. vii.

Legendre in the third supplement of the 'Traité des fonctions elliptiques,' p. 191, gives to the transcendent

$$\int \frac{f(x)\,dx}{\sqrt{X}},$$

and $\theta(x, y) = 0$, this one-valued function being by Abel's theorem an algebraic (and logarithmic) function.

The points (x_i, y_i) $(i = 1, 2, \ldots n)$ are not independent of each other, but as soon as a certain number of them is given, the remaining p (say) are of themselves determined, being the roots of an algebraic equation of the pth degree, whose coefficients are rational functions of those points that are given, so that between these coefficients there exist p algebraic relations.

where $f(x)$ is a rational function of x and X a function of greater degree than the fourth in x, the name ultra-elliptic; when X is of the fifth or sixth degree in x, it is said to be of the *first order*;[1] when X is of the seventh or eight degree in x, of the *second order*, etc. In each order three different *kinds* of integrals are to be distinguished, which are entirely analogous to those 'which the nature of things has introduced into the theory of elliptic functions.'

Jacobi ('Werke,' bd. i. 1832, p. 376) wished to call these the *Abelian transcendents*, on account of the following works of Abel that had at that time appeared :—

'Remarques sur quelques propriétés générales d'une certaine sorte de fonctions transcendantes' (Crelle, bd. iii. 1828, p. 313).

'Démonstration d'une propriété générale d'une certaine classe de fonctions transcendantes' (Crelle, bd. iv. p. 200).

These papers treat of the more special functions in which y is connected with x by the relation $y^2=X$, where X has the same meaning as above; the term *hyperelliptic* is usually applied to such functions, *Abelian* being used *in general* to designate transcendents in which y is defined as any function of x through the algebraic equation $\chi(x, y)=0$.

(13) *Abel's theorem.*—A brief account of some of the fundamental statements of the preceding article is given here. The mode of procedure is nearer that of Riemann, Fuchs, and later writers than that of the original memoir. Some of the results as derived by Abel are given later.

The algebraic equation

$$\chi(x,y)=p_0+p_1y+p_2y^2+\ldots+p_{n-1}y^{n-1}+y^n=\chi(y)=0,$$

in which all the coefficients p are rational integral functions of x, and the integral function

$$\theta(x,y)=q_0+q_1y+q_2y^2+\ldots+q_{n-1}y^{n-1}=\theta(y)=0,$$

where the q's are likewise integral functions of x, when considered geometrically, represent two curves, which intersect in a certain number of points. In the coefficients of these two equations may appear quantities, $u, v, w, \ldots$, quantities quite indeterminate, upon which the coefficients depend.

The co-ordinates of the intersection of the two curves are functions of $u, v, w, \ldots$, so that we may write the two curves in the form

$$\chi(x,y\,;\,u,v,w,\ldots)=0,$$
$$\theta(x,y\,;\,u,v,w,\ldots)=0.$$

Let the points of intersection of the two curves be

$$x_1,y_1\,;\;x_2,y_2\,;\;x_3,y_3\,;\;\ldots x_\mu,y_\mu\,;$$

and when particular values $u^0,v^0,w^0,\ldots$ are given to $u,v,w,\ldots$, let the corresponding points of intersection be

$$x_1{}^0,y_1{}^0\,;\;x_2{}^0,y_2{}^0\,;\;x_3{}^0,y_3{}^0\;\ldots\;x_\mu{}^0,y_\mu{}^0.$$

[1] Legendre uses the word class. We may remark here that, when he divides integrals of the form $\int\frac{x^n dx}{\sqrt{\phi(x)}}$ into the three different *kinds*, he must first assume that n is less than $\frac{\lambda}{2}-1$ or $\frac{\lambda-1}{2}$, where λ is the degree of $\phi(x)$. See Richelot (Crelle, bd. xii. p. 185), where different forms of the integrals corresponding to the different kinds are considered.

Let $\mathrm{R}(x,y)$ be any rational function of x and y, and form the sum

$$\sum_{\kappa=1}^{\kappa=\mu}\int_{x_\kappa^0,y_\kappa^0}^{x_\kappa,y_\kappa}\mathrm{R}(x_\kappa,y_\kappa)dx_\kappa.$$

For the present discussion it is in every respect sufficient to consider only one parameter u, and to specify the function $\theta(x,y)=0$, which we do by writing

$$\theta(x,y)=\phi(x,y)-u\psi(x,y)=0, \qquad (1)$$

$$\text{or } u=\frac{\phi(x,y)}{\psi(x,y)}.$$

The rational function $\dfrac{\phi(x,y)}{\psi(x,y)}$ takes the value u_0 as often as it does any other value u.

Writing

$$\text{(I.)} \qquad w_\kappa=\int_{x_\kappa^0,y_\kappa^0}^{x_\kappa,y_\kappa}\mathrm{R}(x_\kappa,y_\kappa)dx_\kappa,$$

we have

$$\text{(II.)} \qquad \sum_{\kappa=1}^{\kappa=\mu}w_\kappa=\sum_{\kappa=1}^{\kappa=\mu}\int_{x_\kappa^0 y_\kappa^0}^{x_\kappa,y_\kappa}\mathrm{R}(x_\kappa y_\kappa)dx_\kappa.$$

In the expression (II.) we shall study w as a function of u.

From (I.)

$$\frac{dw_\kappa}{du}=\frac{dw_\kappa}{dx_\kappa}\frac{dx_\kappa}{du}=\mathrm{R}(x_\kappa,y_\kappa)\frac{dx_\kappa}{du} \qquad (2)$$

Differentiate (1) with regard to u, and we have

$$\psi(x_\kappa,y\ )+u\left[\left(\frac{\partial\psi}{\partial x}\right)_{\substack{x=x_\kappa\\ y=y_\kappa}}+\left(\frac{\partial\psi}{\partial y}\right)_{\substack{x=x_\kappa\\ y=y_\kappa}}\frac{dy_\kappa}{dx_\kappa}\right]\frac{dx_\kappa}{du}$$

$$-\left[\left(\frac{\partial\phi}{\partial x}\right)_{\substack{x=x_\kappa\\ y=y_\kappa}}+\left(\frac{\partial\phi}{\partial y}\right)_{\substack{x=x_\kappa\\ y=y_\kappa}}\frac{dy_\kappa}{dx_\kappa}\right]\frac{dx_\kappa}{du}=0 \qquad (3)$$

Since $\left(\dfrac{\partial\chi}{\partial y}\right)_{\substack{x=x_\kappa\\ y=y_\kappa}}\dfrac{dy_\kappa}{dx_\kappa}+\left(\dfrac{\partial\chi}{\partial x}\right)_{\substack{x=x_\kappa\\ y=y_\kappa}}=0$, we have, after substituting the value of $\dfrac{dy_\kappa}{dx_\kappa}$ from this equation in (3), a formula for $\dfrac{dx_\kappa}{du}$ which is rational in x_κ, y_κ and u. We may therefore write $\dfrac{dx_\kappa}{du}=\mathrm{S}(x_\kappa,y_\kappa,u)$, where S denotes a rational function.

Further, $\dfrac{dw_\kappa}{du}=\mathrm{R}(x_\kappa,y_\kappa)\ \mathrm{S}(x_\kappa,y_\kappa,u)=\mathrm{T}(x_\kappa,y_\kappa,u)$ where T is also a rational function.

Finally, $\dfrac{d}{du}\displaystyle\sum_{\kappa=1}^{\kappa=\mu}w=\sum_{\kappa=1}^{\kappa=\mu}\mathrm{T}(x_\kappa,y_\kappa,u)=r(u)$, say, where $r(u)$ is a rational function in u.

Hence upon integrating

$$\text{(III.)} \qquad \sum_{\kappa=1}^{\kappa=\mu} w_\kappa = \sum_{\kappa=1}^{\kappa=\mu} \int_{x_\kappa^0, y_\kappa^0}^{x_\kappa, y_\kappa} \mathrm{R}(x_\kappa, y_\kappa) dx_\kappa = \int r(u)\, du.$$

We note that the number μ does not depend upon the function $\mathrm{R}(x,y)$.

(14) We thus have the sum of μ integrals expressed as the integral of a rational function of the parameter u. This integral depends upon the nature of the function $\mathrm{R}(x,y)$ being, first, a constant; secondly, the differential of a logarithmic function which is equivalent to a determinate algebraic function; thirdly, a logarithmic expression which likewise is determinate, when the integral $\int \mathrm{R}(x,y)dx$ are special integrals of the *first*, *second*, and *third* kinds respectively.

The discussion of these special integrals, the normal integrals of the first, second and third kinds, is found in Forsyth, 'Theory of Functions,' p. 443; Harkness and Morley, 'A Treatise on the Theory of Functions,' p. 435; Neumann, 'Theorie der Abel'schen Integrale,' p. 245, &c.

(15) Nöther [1] has proved that any algebraic curve may by means of birational transformations be transformed into another curve in which the highest singularities are double points with distinct tangents. We may therefore assume that the curve $\chi(x,y)=0$ has no higher singularities than these. Upon this hypothesis the most intricate integral that arises may be expressed linearly in terms of the normal integrals of the first, second and third kinds, with the addition, perhaps, of an algebraic expression.

Abel allowed the curve $\chi(x,y)=0$ to have any kind of singularity; and hence the expression for the algebraic and logarithmic functions that stand on the right of formula (III.) in art. 13 are necessarily very complicated. By making use of the methods mentioned above, this complexity is avoided, and the representation of the integral $\int r(u)du$ may be obtained in comparatively simple form.

(16) Denote the p linearly independent normal integrals of the first kind by $v_h(x,y)(h=1, 2, \ldots p)$; then, as in art. 13,

$$\sum_{\kappa=1}^{\kappa=p} \int_{x^0_\kappa, y^0_\kappa}^{x_\kappa, y_\kappa} dv_h(x,y)dx \equiv 0 \text{ (mod. } const.\text{)},$$

$$\text{or} \sum_{\kappa=1}^{\kappa=q} \int_{x_\kappa^0, y_\kappa^0}^{x_\kappa, y_\kappa} dv_h(x,y)dx + \sum_{\kappa=1}^{\kappa=p} \int_{x^0_{q+\kappa}, y^0_{q+\kappa}}^{x_{q+\kappa}, y_{q+\kappa}} dv_h(x,y)dx \equiv 0 \text{ (mod. const.)},$$

where $p+q=\mu$.

The points x^0_κ, y^0_κ $(\kappa = 1, 2, \ldots q)$; $x^0_{q+\kappa}, y^0_{q+\kappa}$ $(\kappa = 1, 2, \ldots p)$ and the points x_κ, y_κ $(\kappa = 1, 2, \ldots q)$ may be chosen at pleasure; but the remaining p points $x_{q+\kappa}, y_{q+\kappa}$ $(\kappa = 1, 2, \ldots p)$ are no longer arbitrary, the x's being the roots of an algebraic equation of the pth degree

$$x^p + a_1 x^{p-1} + a_2 x^{p-2} + \ldots + a_p = 0,$$

[1] Nöther, *Math. Ann.* bd. ix. p. 17; see also Halphen, *Bulletin de la Soc. Math. de France*, t. iv. Dec. 1875, and t. iii. Feb. 1875; Bertini, *Revista di Matem.* 1891, and *Math. Ann.* bd. xliv. p. 158; Poincaré, *Compt. Rend.* July 1893.

where the constants $a_1, a_2, \ldots a_p$ are determinate rational functions of the other points,

$$x^0_\kappa, y^0_\kappa \ (\kappa = 1, 2 \ldots q) \ ; \ x^0_{q+\kappa}, y^0_{q+\kappa} \ (\kappa = 1, 2 \ldots p)$$
$$\text{and } x_\kappa, y_\kappa \ (\kappa = 1, 2 \ldots q).$$

The corresponding values of y are the remaining ordinates of the points of intersection of the curves $\chi(x,y) = 0$, and $\theta(x,y) = 0$.

(17) Abel, in the proof of his theorem, stated in art. 12 wrote :

$$\phi(x) = \int f(x,y)\, dx,$$

where $f(x,y)$ is any rational algebraic function of x and y. He then considered the sum of such integrals

$$\sum_{i=1}^{i=\mu} \phi(x_i),$$

where x_i ($i = 1, 2, \ldots \mu$) are the points of intersection of the two curves $\chi(x,y) = 0$, $\theta(x,y) = 0$; that is, the roots of the equation $E(x) = 0$, which is obtained by eliminating y out of the two given equations.

Of these points of intersection some may be stationary, while the others are movable, the fixed points being independent of the parameters $u, v, w, \ldots$ (art. 13). Hence $E(x)$ may be composed of two factors $F_0(x)$ and $F(x)$, of which $F_0(x)$ does not depend upon $u, v, w, \ldots$

Abel wrote the subject of integration in the form

$$\frac{f_1(x,y)}{f_2(x,y)\,\chi'(y)},$$

where $f_1(x,y)$ and $f_2(x,y)$ are integral functions of x and y and $\chi'(y) = \frac{\partial\chi(x,y}{\partial y}$.

He found that $\displaystyle\sum_{i=1}^{i=\mu} \phi(x_i) = \sum_{i=1}^{i=\mu} \frac{f_1(x_i, y_i)}{f_2(x_i, y_i)\,\chi'(y_i)} dx_i = v,$

where v may be a constant *plus* an algebraic function *plus* a logarithmic function. (A concise expression for v, due to Rowe, is given in art. 20.)

(18) After restricting the functions $f_1(x,y)$, $f_2(x,y)$ and $F_0(x)$ in such a way that the logarithmic and algebraic functions of the expression above disappeared, Abel found that the function $f_1(x,y)$ contained a certain number of arbitrary constants, a number which depended only upon the nature of the curve $\chi(x,y) = 0$. This number he designated by $\gamma (= p$, of art. 13).

In the equation $\theta(x,y) = q_0 + q_1 y + q_2 y^2 + \ldots + q_{n-1} y^{n-1} = 0$, a certain number of the coefficients of x in the functions q are supposed indeterminate. Denote these by $a, a_1, a_2, \ldots$ We saw above that the upper limits $x_i (i = 1, 2, \ldots \mu)$ of the integrals in (I.) are the roots of the equation $E(x) = 0$, and may be expressed as functions of the independent quantities $a, a_1, a_2, \ldots$, of which there are, say, a.

Let these functions be :

$$x_1 = f_1(a, a_1, a_2, \ldots), x_2 = f_2(a, a_1, a_2, \ldots) \ldots x_\mu = f_\mu(a, a_1, a_2, \ldots).$$

From these relations it is seen that as soon as a of the x's are given, the remaining $\mu - a$ may be determined in terms of the known ones. Abel showed how to effect this determination, and in general that $\mu - a = \gamma$.

In two special cases considered by Abel this number is less than γ. (See also Rowe, Memoir on Abel's Theorem, 'Phil. Trans.' 1881, p. 731.) Professor Cayley, in the 'Addition to Mr. Rowe's Memoir,' proved that γ was always equal to the deficiency of the curve $\chi(x,y) = 0$, whatever its singularities.

Professor H. F. Baker has recently proved the same theorem by means of graphic methods in the 'Cambr. Trans.' xv. Part IV.; see also 'Math. Ann.,' 45, p. 133.

As a special case Abel gave the equation $\chi(x,y) = 0$ the form $y^n + p_0 = 0$.

The form of the integrals whose sum is to be expressed as in formula (I.) is

$$\int \frac{f_3(x)dx}{f_2(x)y^m}.$$

For the hyperelliptic functions ($n = 2$), when p_0 is of the $2m - 1^{\text{st}}$ or $2m^{\text{th}}$ degree, Abel showed that $\mu - a = m - 1$.

(19) Mathematicians were much interested in the new functions which must be introduced in connection with the Abelian integrals. The Academy at Copenhagen wished to see these functions extended to all integrals of algebraic functions, which are included in Abel's theorem;[1] and in regard to this wish Jürgensen, Broch, Minding, Rosenhain wrote some very important memoirs. The value of these memoirs, however, on account of their less generality was much diminished when Abel's great paper was finally published in 1841.

Minding, in two short papers (Crelle, bd. ix. p. 295, 1833, and bd. xi. p. 233, 1834), showed how to represent the algebraic and logarithmic functions of Abel's theorem for the special cases in which the algebraic functions satisfy an equation of the third degree.

Jürgensen ('Sur la Sommation des Transcendantes à différentielles algébriques,' Crelle, bd. xix. p. 113), took, as the subject of integration, the quotient of two functions $P(x, z_i)$ and $Q(x, z_i)$, where P and Q are integral functions, and where z_i is a root of an equation that is similar to Abel's $\chi(x,y) = 0$.

After reducing $\dfrac{P(x, z_i)}{Q(x, z_i)}$ to a form $\dfrac{\lambda(x, z_i)}{\nu(x)}$, where λ and ν denote integral functions (see Liouville, 'Note sur la Détermination des intégrals dont la valeur est algébrique,' Crelle, bd. x. p. 347),[2] he considered a sum of integrals of the form $\displaystyle\int \frac{\lambda(x, z_i),}{\nu(x)}$ where the summation is taken over the μ roots of the resultant of two algebraic equations. This sum he expressed in the form of an algebraic and logarithmic function.

In a second paper (Crelle, bd. xxiii. p. 126) Jürgensen denoted by $X(x, y_i)$

[1] *Cf.* Jacobi, *Gesam. Werke*, bd. ii. p. 517. He does not mention Jürgensen.

[2] See also references cited in art. 11, and a paper by Liouville, *Sur l'intégration d'une classe de fonctions transcendantes*, bd. xiii. p. 93.

a rational function of x and any one of the n roots y_i $(i=1, 2, \ldots n)$ of the equation

$$y^n+p_1 y^{n-1}+p_2 y^{n-2}+ \ldots +p_{n-1}y+p_n=0,$$

the p's being integral functions of x; then X (see Liouville's paper mentioned above) may be given one or the other of the forms

$$X=\frac{f(x)}{\phi_\kappa(x)} \text{ or } X=f(x)\,\phi_\kappa(x),$$

where $f(x)$ is a rational function of x, and $\phi_\kappa(x)$ is an integral function of x and y_κ.

Two leading questions are considered: (1) To find the cases in which one can express $\int Xdx$ by a finite number of algebraic and logarithmic operations (see art. 34); (2) To find the relations among the integrals

$$\int f(x_1)\phi_\kappa(x_1)dx_1, \quad \int f(x_2)\phi_h(x_2)dx_2, \ldots$$

which correspond to variables $x_1, x_2, \ldots$ that depend upon one another, and upon the different roots $y_\kappa, y_h, \ldots$.

Broch, 'Mémoire sur les fonctions de la forme,'

$$\int x^{s-\gamma p-1} f(x^p) \left(\mathrm{R}(x^p)\right)^{\pm\frac{s}{\gamma p}} dx,\text{'}$$

(Crelle, bd. xxiii. p. 148, 1841), developed rules for the summation of the transcendents mentioned in the title, where $f(x^p)$ is a rational function of x^p, γ an integer which is divisible by $\frac{s-1}{\gamma}$, r and p are integers, and s an integer less than $r.\ p$.

These are analagous to the investigations of Abel on the hyperelliptic functions which had already been published.

In a previous memoir (Crelle, bd. xx. p. 178), Broch had discussed the special case where $p=1$ and $s=1$. The basis of this paper is Abel's memoir, 'Démonstration d'une propriété générale,' &c. Broch also sought the minimal number of integrals (Abel's γ), through which a sum of integrals could be represented.

Minding divided his paper, 'Propositiones quædam de integralibus functionum algebraicarum,' &c. (Crelle, bd. xxiii. p. 255), into three heads. He first gives an expression for a sum of integrals of the form

$$\int\frac{\phi_o(x_i)\ \mathrm{F}(x_i, y_i p_o)\,dx_i}{\phi(x_i)},$$

when ϕ_o and F are integral functions, and

$$\phi(x)=(x-c_1)(x-c_2)\ \ldots\ (x-c_r),$$

the c's denoting constants. x_i and y_i are the common intersections of two curves

$$p_0 y^n+p_1 y^{n-1}+ \ldots +p_n=0\ ;\ q_1 y^{n-1}+q_2 y^{n-2}+ \ldots +q_n=0,$$

which correspond to Abel's $\chi(x,y)=0$ and $\theta(x,y)=0$.

Minding further allowed arbitrary variable parameters in his functions q, so that his results, as Brill and Nöther[1] remark, are only less general than those of Abel in that fixed points of intersection of the two curves are not considered.

[1] *Jahresber. der deutschen Mathematiker-Vereinigung*, bd. iii. p. 229.

The contents of the second head are indicated by its title 'De numero minimo integralium ad quæ numerus datus eiusmodi integralium reduci potest.'

In the third head he makes application of the preceding theorems to the equation: $p_0 y^n + p_n = 0$. (See also art. 19.)

Ramus (Crelle, bd. xxiv. p. 69) derives a formula for the expression of the sum of μ integrals $\psi(x_1)+\psi(x_2)+\ .\ .\ .\ +\psi(x_\mu)$, where $\psi(x)$ has either the form $\int \frac{f(x)}{x-a} y^m(x)\,dx$ or $\int \frac{f(x)}{x-a}\,\frac{dx}{y^m(x)}$, where $f(x)$ is an integral function of x, m a positive integer, and $y^m(x)$ is one of the n roots $y_1(x)$, $y_2(x)$, . . $y_n(x)$ of the equation

$$0 = p_0 + p_1 y + p_2 y^2 + \ .\ .\ .\ p_{n-1} y^{n-1} + y^n.$$
$$(\text{Abel's } \chi(x,y)=0.)$$

The variables x_i $(i=1, 2, \ .\ .\ .\ \mu)$ are the points of intersection of this curve with a second algebraic curve.

Rosenhain (Crelle, bd. xxviii. p. 249, 1844) employed as fundamental equation

$$\phi(x,y) = p_0 y^n + p_1 y^{n-1} + \ .\ .\ .\ + p_n = 0.$$

in the place of Abel's $\chi(x,y)=0$.

Proceeding in a manner very similar to that of Abel, he adopts in his summation-formula integrands of the form

$$\frac{Q_2 y^{n-2} + Q_3 y^{n-3} + \ .\ .\ .\ + Q^n}{\phi'(y)},$$

where the Q's are the rational functions of x.

In discussing the hyperelliptic case $(n=2)$ he gives $\phi(x,y)$ the form $p_0 y_2 + p_1 y + p_2$, and not the form usually adopted, $y^2 = R(x)$, p_0, p_1, p_2, and R denoting rational functions of x.

He then seeks to prove in the general case that the number of arbitrary constants in an integral of the first kind is equal to the smallest number of integrals through which the sum of any number of such integrals is expressible. The article is continued (Crelle, bd. xxix. p. 1).

(20) Boole, in a paper, 'On the Comparison of Transcendents, with certain Applications to the Theory of Definite Integrals' ('Phil. Trans.' 1857, p. 745), contemplates the following objects:

First, the demonstration of a fundamental theorem for the summation of integrals, whose limits are determined by the roots of an algebraic equation. Secondly, the application of that theorem to the comparison of algebraic transcendents. Thirdly, the application of the same theorem in a new, and, as it is conceived, more remarkable line of investigation to the comparison of functional transcendents. In the introduction to this paper, Boole states: 'As presented in the writings of Abel and of those who immediately followed in his steps, the doctrine of the comparison of transcendents is repulsive from the complexity of the formulæ in which the general conclusions are embodied.' With the intention of simplifying these formulæ, Boole introduced a symbol differing in interpretation only by the addition of one element from the symbol used by Cauchy in the 'Calculus of Residues.'

This symbol, Θ, he defines as follows: 'If $\phi(x) f(x)$ be any function of x composed of two factors $\phi(x)$ and $f(x)$, whereof $\phi(x)$ is rational, let $\Theta[\phi(x)]\cdot f(x)$ denote the result obtained by successively developing the

function in ascending powers of each distinct simple factor (of the form) $x-a$ in the denominator of $\phi(x)$, taking in each development the coefficient of $\frac{1}{x-a}$, adding together the coefficients thus obtained from the several developments, and subtracting from the result the coefficient of $1/x$ in the development of the same function in descending powers of x.'

The simplifications made by Boole are more than offset by the loss of generality which characterise his formulæ.

Rowe (Memoir on Abel's Theorem, 'Phil. Trans.' 1881, p. 713) endeavoured to simplify Abel's results, and at the same time to retain their generality. Using the same notation as in art. 18, and employing Boole's symbol, he derives Abel's theorem in the form :

$$\sum \int f(x,y)dx = \sum \int \frac{f_1(x, y)dx}{f_2(x, y)\chi'(y)}$$

$$= \Theta\left[\frac{1}{f_2(x)\mathrm{F}_0(x)}\right] \mathrm{F}_0(x) \sum \frac{f_1(x, y)}{\chi'(y)} \log \theta(y) + \mathrm{C},$$

where C is a constant.

Professor A. R. Forsyth, in a paper, 'Abel's Theorem and Abelian Functions' ('Phil. Trans.' 1883, p. 323) has obtained an expression for an integral that is more general than that occurring in Abel's theorem.

Professor Forsyth takes two given equations of degrees m and n between three variables, of which y and z are dependent, x being independent :

$$\mathrm{F}_m(x, y, z)=0, \; \mathrm{F}_n(x, y, z)=0.$$

The Jacobian (functional-determinant) of these two functions is denoted by $\mathrm{J}\left(\frac{\mathrm{F}_m, \mathrm{F}_n}{y, z}\right)$. A quantity T is defined by the relation

$$\mathrm{T}=\frac{\Psi(x, y, z)}{\Phi(x, y, z)},$$

where Ψ and Φ are rational algebraic functions of x, y, z. This quotient may in turn be expressed in the form $\frac{\mathrm{U}}{f(x)}$, where U is an integral function of x, y, and z, and $f(x)$ a function of x alone.

The generalised Abel's theorem, as derived by Professor Forsyth, is

$$\sum \int \frac{\mathrm{U}dx}{f(x)\mathrm{J}\left(\frac{\mathrm{F}_m, \mathrm{F}_n}{y, z}\right)} = \Theta\left[\frac{1}{f(x)}\right] \sum \left\{\frac{\mathrm{U}}{\mathrm{J}\left(\frac{\mathrm{F}_m, \mathrm{F}_n}{y, z}\right)} \log \mathrm{F}_p\right\} + \mathrm{C},$$

where the upper limits of the integrals on the left-hand side are the $m.n.p$ roots of the equation obtained by eliminating y and z between F_m and F_n, and an arbitrary rational algebraic function $\mathrm{F}_p(x,y,z)=0$. On the right-hand side the summation extends over the $m.n$ roots y and z in terms of x of the equations $\mathrm{F}_m=0$ and $\mathrm{F}_n=0$. C is a constant.

The more general theorem Professor Forsyth enunciates as follows : Let $\mathrm{F}_i(x_1, x_2, \ldots x_r)=0$ $(i=1, 2, \ldots r-1)$ be $r-1$ algebraic equations of degrees $m_1, m_2, \ldots m_{r-1}$ respectively, giving $x_2, x_3, \ldots x_r$ in terms of x_1 ; and let $\mathrm{F}_r(x_2, x_3, \ldots x_r)$ be a function of these dependent variables, the coefficients of which are functions of x, containing any number of arbitrary constants. Form the eliminant E of all the F's, so that we

shall obtain the set of roots x_1 by equating E to zero; and denote by U any algebraic function of $x_1, x_2, \ldots x_r$.

Then

$$\Sigma\int\frac{\mathrm{U}}{f(x_1)}\frac{dx_1}{\mathrm{J}\left(\dfrac{\mathrm{F}_1,\ \mathrm{F}_2,\ \ldots\ \mathrm{F}_{r-1}}{x_2,\ x_3,\ \ldots\ x_r}\right)}=\Theta\left[\frac{1}{f(x_1)}\right]\Sigma\frac{\mathrm{U}\log\mathrm{F}_r}{\mathrm{J}\left(\dfrac{\mathrm{F}_1,\ \mathrm{F}_2,\ \ldots\ \mathrm{F}_{r-1}}{x_2,\ x_3,\ \ldots\ x_r}\right)}+\mathrm{A}.$$

The summation on the right-hand side is taken over all the roots of $\mathrm{E}=0$, which are assumed as the upper limits of the integrals; while on the right-hand side the summation is over all the roots $\mathrm{F}_1=0$, $\mathrm{F}_2=0$, ... $\mathrm{F}_{r-1}=0$, considered as $r-1$, simultaneous equations giving $x_2, x_3, \ldots x_r$ in terms of x_1.

In connection with this paper we note a paper by Professor Cayley, 'A Memoir on the Abelian and Theta Functions' ('American Journ. Math.' vol. v. p. 137, and vol. vii. p. 101).

The first chapter treats of Abel's theorem; the second, a proof of Abel's theorem. The connection between the lines of thought presented in this paper and those of Professor Forsyth are particularly interesting. In the further developments of Professor Cayley's paper, which is founded upon Clebsch and Gordan's 'Treatise,' some geometrical results are brought into prominence. The theory is illustrated by examples in regard to the cubic, the nodal quartic and the general quartic respectively.

The general case where the fixed curve is any curve whatever has been solved with great generality by Nöther,[1] 'Zur Reduction Algebraischer Differentialausdrücke auf der Normalform,' and 'Ueber die Algebraischen Differentialausdrücke' ('Sitzungsber. der Phys. Med. Soc. zu Erlangen,' Dec. 10, 1883, and Jan. 14, 1884). Other addition-theorems, especially for the hyperelliptic functions, are given in art. 32.

(21) *Periodic Functions of Several Variables.*—In art. 10 the periodic properties of functions of one variable were considered, and it has been seen that Abel's theorem embraces the integrals of all algebraic functions. Considering the inverse of these transcendental integrals, Jacobi discovered the existence of the *periodic functions of several variables*, and thus revealed the real significance and hitherto hidden properties of such functions.

Some of Jacobi's investigations [2] relative to hyperelliptic transcendents are next given, since they may be used to illustrate Abel's theorem for the more general integrals, and set forth the properties of the inverse functions that are comprised in this theorem.

If X denotes a rational integral function of the fourth degree in x, then by Euler's theorem (art. 5) transcendents of the form

$$\int_0^x\frac{dx}{\sqrt{\mathrm{X}}}=\Pi(x)$$

enjoy the singular property that if

$$\Pi(x_1)+\Pi(x_2)=\Pi(a),$$

then a may be found algebraically in terms of x_1 and x_2. Owing to

[1] See also Nöther, *Math. Ann.* bd. ii. p. 314, bd. ix. p. 17; Brill and Nöther, *Math. Ann.* bd. vii. p. 269, and continuation in bd. vii.; Klein-Fricke, *Elliptische Modulfunctionen*, bd. i. 1890, p. 533; Baker, *Cambridge Phil. Trans.* xv.; *Math. Ann.* bd. xlv. p. 133, &c.

[2] Jacobi, *Considerationes Generales de Transcendentibus Abelianis*, Crelle, bd. ix. p. 394, 1832; *Werke*, bd. ii. p. 7.

Abel's theorem, analogous properties exist for all such transcendents, in which the function X is any rational integral function of x. For, taking the next simplest case, let X be of the fifth or sixth degree in x, and write :

$$\int_0^x \frac{dx}{\sqrt{X}}=\Phi(x),\ \int_0^x \frac{xdx}{\sqrt{X}}=\Phi_1(x);$$

and further write :

$$\Pi(x)=\int_0^x \frac{(A+A_1x)dx}{\sqrt{X}},$$

or

$$\Pi(x)=A\Phi(x)+A_1\Phi_1(x),$$

where A and A_1 denote constants.

Then from Abel's theorem it follows that of the innumerable solutions of the equation

$$(1)\quad \Pi(x_1)+\Pi(x_2)+\Pi(x_3)=\Pi(a)+\Pi(b),$$

there is one algebraic solution; that is, a and b may be algebraically determined in terms of x_1, x_2, x_3 from the two equations that are derived from (1) :

$$\Phi(x_1)+\Phi(x_2)+\Phi(x_3)=\Phi(a)+\Phi(b),$$
$$\Phi_1(x_1)+\Phi_1(x_2)+\Phi_1(x_3)=\Phi_1(a)+\Phi_1(b).$$

(22) In general, if we write :

$$\int\frac{(A+A_1x+A_2x^2+\ .\ .\ .\ +A_{m-2}x^{m-2})dx}{\sqrt{X}}=\Pi(x),$$

where $X=f(x)$ is a rational integral function of the $2m$th or $2m-1$th degree in x, it follows from Abel's theorem that, if m values $x_1, x_2, \ldots x_m$ of the variable x be given, through these m quantities it is possible to determine (art. 18) in an *algebraic* manner $m-1$ quantities $a_1, a_2, \ldots a_{m-1}$, which satisfy the transcendental relation :

$$\Pi(x_1)+\Pi(x_2)+\ .\ .\ .\ +\Pi(x_m)=\Pi(a_1)+\Pi(a_2)+\ .\ .\ .\ +\Pi(a_{m-1});$$

and Abel further showed that the quantities $a_1, a_2, \ldots a_{m-1}$ are the roots of an algebraic equation of the $m-1$th degree, and that each of the coefficients in this algebraic equation may be rationally expressed in terms of the quantities : $x_1, x_2, \ldots x_m$, and

$$\sqrt{X_1},\ \sqrt{X_2},\ \ldots\ \sqrt{X_m},\ \text{where } X_\lambda=f(x_\lambda)\ {\scriptstyle(\lambda=1,2\ldots m)}.$$

It also follows from Abel's theorem that, when any number whatever of values of x are given, the sum of the transcendents $\Pi(x)$ which belong to given values of x may be expressed through $m-1$ transcendents $\Pi(x)$ when the $m-1$ values of x in these transcendents are algebraically determined from the given values.

(23) We consider next the case where the sum of four transcendents are expressed as the sum of two, and where the arguments of these two transcendents depend algebraically upon the arguments of the first four. As above, we write :

$$\int_0^x\frac{dx}{\sqrt{X}}=\Phi(x)\text{ and }\int_0^x\frac{xdx}{\sqrt{X}}=\Phi_1(x).$$

By Abel's theorem, when the two equations

$$(1)\begin{cases}\Phi(a)+\Phi(b)=\Phi(x_1)+\Phi(x_2)+\Phi(x_3)+\Phi(x_4),\\ \Phi_1(a)+\Phi_1(b)=\Phi_1(x_1)+\Phi_1(x_2)+\Phi_1(x_3)+\Phi_1(x_4)\end{cases}$$

are simultaneously given, a and b are algebraically determined in terms of the given quantities x_1,x_2,x_3,x_4.

Now write

$$(2)\begin{cases}\Phi(x_1)+\Phi(x_2)=u,\\ \Phi_1(x_1)+\Phi_1(x_2)=v\,;\end{cases}\qquad (2')\begin{cases}\Phi(x_3)+\Phi(x_4)=u',\\ \Phi_1(x_3)+\Phi_1(x_4)=v'.\end{cases}$$

Then from (1) it follows that

$$(3)\begin{cases}\Phi(a)+\Phi(b)=u+u',\\ \Phi_1(a)+\Phi_1(b)=v+v'.\end{cases}$$

If now in (2) we consider x_1 and x_2 as functions of u and v and write $x_1=\lambda(u,v), x_2=\lambda_1(u,v)$, and similarly in (2′) write $x_3=\lambda(u',v')$, $x_4=\lambda_1(u',v')$, then it follows from (3) that $a=\lambda(u+u',v+v')$, $b=\lambda_1(u+u',v+v')$.

Since a and b are algebraically expressible in x_1,x_2,x_3,x_4, it follows that $\lambda(u+u',v+v')$ and $\lambda_1(u+u',v+v')$ are algebraically expressible in terms of $\lambda(u,v,)$ $\lambda_1(u,v)$, $\lambda(u',v')$ and $\lambda_1(u',v')$.

The general theorem may be expressed as follows:

$$\text{Let}\int_0^x \frac{x^i dx}{\sqrt{\mathrm{X}}}=\Phi_i(x),\ i=(0,1,\ldots m-2),$$

where $\mathrm{X}=f(x)$ is a rational integral function of the $2m$th or $2m-1$th degree in x, then, if between the $m-1$ quantities $x_0,x_1,\ldots x_{m-2}$ and the quantities $u_0,u_1,\ldots u_{m-2}$ the following equations exist simultaneously,

$$\text{(I.)}\quad u_i=\Phi_i(x_0)+\Phi_i(x_1)+\ldots+\Phi_i(x_{m-2}),\quad (i=0,1,\ldots m-2)\,;$$

and if

$$\text{(II.)}\quad x_i=\lambda_i(u_0,u_1,\ldots u_{m-2}),\quad (i=0,1,\ldots m-2)\,;$$

with equations similar to (I.) and (II.) with accented u's and x's, then these functions enjoy the same property as do the trigonometric and elliptic functions, viz.:

The functions

$$\lambda_i(u_0,+u_0',u_1+u_1',\ldots u_{m-2}+u'_{m-2})$$

may be algebraically expressed through the functions

$$\lambda_i(u_0,u_1,\ldots u_{m-2})\text{ and }\lambda_i(u'_0,u'_1,\ldots u'_{m-2}),$$
$$(i=0,1,\ldots m-2).$$

(24) *Integrals of differential equations.*—Euler's theorem sets forth the complete algebraic integral of a differential equation of the first order with two variables, which have been separated in such a way that

$$\frac{dx_1}{\sqrt{\mathrm{X}_1}}+\frac{dx_2}{\sqrt{\mathrm{X}_2}},$$

where X_1 and X_2 denote the same rational integral function of the fourth degree in x_1 and x_2 respectively; and Euler[1] showed that the algebraic integral was an equation of the second degree between the two quantities x_1+x_2 and $x_1.x_2$.

Abel's theorem sets forth *algebraically* $m-1$ complete integrals (integrals which involve $m-1$ arbitrary constants) of $m-1$ differential

[1] Euler, *Institutiones Calc. Int.* t. i. cap. vi. § 2.

equations of the first order with m variables, in each of which the m variables are separated.

Taking the next simplest case, let $X=f(x)$ denote a rational integral function of the fifth or sixth degree. Then the two transcendental equations (see the preceding article)

$$\Phi(x_1)+\Phi(x_2)+\Phi(x_3)=\Phi(a)+\Phi(b),$$
$$\Phi_1(x_1)+\Phi_1(x_2)+\Phi_1(x_3)=\Phi_1(a)+\Phi_1(b),$$

owing to Abel's theorem, take the place of two algebraic equations between the five qualities x_1, x_2, x_3, a and b. Consider a and b as constants. Then, when we differentiate the two equations just written, the terms involving a and b drop out, so that these quantities appear as arbitrary constants in the transcendental equations, or in the algebraic equations which take the place of the transcendental.

Hence we have the following theorem : Let $f(x)$ be a rational integral function of the fifth or sixth degree in x, and write $f(x_i)=X_i$, $(i=1, 2, 3)$, then the differential equations of the first order with three variables,

$$(\sigma.)\quad \frac{dx_1}{\sqrt{X_1}}+\frac{dx_2}{\sqrt{X_2}}+\frac{dx_3}{\sqrt{X_3}}=0\,;\ \frac{x_1dx_1}{\sqrt{X_1}}+\frac{x_2dx_2}{\sqrt{X_2}}+\frac{x_3dx_3}{\sqrt{X_3}}=0$$

have two complete algebraic integrals.

This theorem is easily extended to $m-1$ linear differential equations of the first order with m variables, in each of which the variables are separated :

$$(\Sigma.)\quad \frac{x^i{}_1dx_1}{\sqrt{X_1}}+\frac{x^i{}_2dx_2}{\sqrt{X_2}}+\ .\ .\ .\ +\frac{x^i{}_mdx_m}{\sqrt{X_m}}=0,$$
$$(i=0,\ 1,\ 2\ .\ .\ .\ m-2),$$

where X_1, X_2, . . . X_m denote the same integral functions in x_1,x_2, . . . x_m. Jacobi closes the 'Considerationes generales,' &c. with the remarks : 'We know that Lagrange, starting with the differential equation between two variables [art. 7] came to its complete algebraic integral through direct methods of integration, and so by a new and singular method demonstrated Euler's theorem ; and so we think it worth the while to investigate through direct methods of integration the two complete algebraic integrals of the system $(\sigma.)$ above, or more generally the $m-1$ complete algebraic integrals of the system $(\Sigma.)$, and thus adorn Abel's theorem with a new and no less singular demonstration.'

At the end of the 'Note von der geodätischen Linie auf einem Ellipsoid,' &c. ('Werke,' bd. ii. p. 59), Jacobi finds that by making use of a certain substitution he was able to extend the remarkable relation discovered by Legendre between the complete integrals of the first and second kind of two elliptic integrals whose moduli are complements to each other to all hyperelliptic integrals ; and this same substitution, he says, led him to the Abelian theorem itself in a way and through considerations which are absolutely different from that of Abel. These considerations originate from a mechanical problem.

The elliptic movement of a planet, or even the motion of a point in a straight line, may be expressed through an equation between two elliptic integrals. We have two methods of treating the same problem, of which the one represents the solution in a transcendental, the other in an

algebraic form. We thus derive a new method of finding the fundamental theorem for the addition of elliptic integrals. Jacobi says that by generalising this method through the introduction of any number of variables he obtained the general addition-theorem in a new and ready manner; and at the same time there was opened a simpler way, through the application of suitable multiplications, of coming directly to the algebraic integrals of the systems of differential equations (σ.) and (Σ.) above. See also a paper by Haedenkamp (Crelle, bd. xxii. p. 184).

(25) Following Jacobi's suggestion of the preceding article, Richelot (Crelle, bd. xxiii. p. 354) extended Lagrange's methods (art. 7) and in a direct manner integrated the differential equations (σ.) and (Σ.)[1] above.

By his methods two algebraic integrals are found for Euler's differential equation, of which it is easy to prove that the one is a function of the other; while the two algebraic solutions of (σ.) are independent. He found two similar solutions for the system (Σ'.) The general solution of this system of equations he derived in the following form: In system (Σ'.) let $X=f(x)=A_0+A_1x+A_2x^2+\ldots A_{2n}x^{2n}$, and for brevity write $F(x)=(x-x_1)(x-x_2)\ldots(x-x_n)$ and $F'(x)=\dfrac{\partial F(x)}{\partial x}$; if, next, the roots of the equation.

$$(a_0+a_1x+a_2x^2+\ldots+a_nx^n)^2-b^2(A_0+A_1x+\ldots+A_{2n}x^{2n})=0$$

be denoted by $x_1, x_2, \ldots x_n, m_1, m_2, \ldots m_n$, and if the coefficients $a_0, a_1, \ldots b$ be determined through the *first* $n+1$ of these roots, then the $n-1$ equations of condition, which must exist in order that the $n-1$ remaining quantities $m_2, m_3 \ldots m_n$ be the roots of this equation, are the $n-1$ complete algebraic integrals of the system (Σ'.).[2]

Richelot assumed that $f(x)$ has, as factors, $x-\alpha_0$, $x-\alpha_1, \ldots x-\alpha_{n-1}$, and for brevity he wrote

$$P(x)=(x-m_2)(x-m_3)\ldots(x-m_n);\ m_1=\alpha_0.$$

[1] Change m into n in the system (Σ.) in order to have the system adopted by Richelot, which denote by (Σ'.).

[2] It is interesting to note here certain difficulties that the older mathematicians experienced. Euler (*Inst. Cal. Int.* t. i., cap. vi. § 2, prob. 82, scholion 1) says it is quite clear that transcendents of the form $\int\dfrac{dx}{\sqrt{A+Bx+Cx^2+Dx^3+Ex^4+Fx^5+Gx^6}}$ cannot be treated in the manner of circular and elliptic integrals; for if the coefficients are restricted so that the root may be extracted, the formula becoming $\int\dfrac{dx}{a+bx+cx^2+dx^3}$, it can in no wise happen that several functions of this kind be algebraically compared among one another. Lagrange tried in vain to extend this theorem. This paradoxical thought is easily explained: for two algebraic equations between the arguments of the integrals always satisfy the two transcendental relations between these integrals when the function under the radical sign is of the fifth or sixth degree (art. 24). These algebraic equations exist owing to the fact that the numerator of the integral which is of the first degree has coefficients which are always of such a nature that two of the arguments become roots of a quadratic equation, whose roots involve the other arguments algebraically. As often, therefore, as the transcendents unite within themselves a logarithmic and a trigonometric part, it happens through the algebraic equations that both the trigonometric and the logarithmic parts vanish independently in the two transcendental equations, so that one relation is given among the logarithms and another among the arcs. *Cf.* Richelot (Crelle, bd. ii. p. 181).

After some reductions he was able to express the $n-1$ integrals of the system (Σ'.) in the form,

$$\mathrm{F}(a_h)\left\{\frac{\sqrt{f(x_1)}}{\mathrm{F}'(x_1)}\cdot\frac{1}{a_h-x_1}+\frac{\sqrt{f(x_2)}}{\mathrm{F}'(x_2)}\cdot\frac{1}{a_h-x_2}+\ldots+\frac{\sqrt{f(x_n)}}{\mathrm{F}'(x_n)}\,\frac{1}{a_h-x_n}\right\}^2$$
$$=-\mathrm{A}_{2n-1}\,\mathrm{P}(a_h),$$
$$(h=1,2,\ldots n-1).$$

One recognises at once much similarity between the quantities employed here and those later used by Weierstrass in Crelle, bd. xlviii.

(26) Jacobi ('Demonstratio nova theorematis Abeliani,' Crelle, bd. xxiv. p. 28), derived the $n-1$ algebraic integrals in a different manner than that given above, and at the same time he established a new proof of Abel's theorem. Instead of the system (Σ.) he introduced n differential equations with n variables $\lambda_1, \lambda_2, \ldots \lambda_n$ and the variable t:

$$(\Sigma.'')\left\{\begin{array}{l}\dfrac{\lambda_1{}^i\,d\lambda_1}{\sqrt{f(\lambda_1)}}+\dfrac{\lambda_2{}^i\,d\lambda_2}{\sqrt{f(\lambda_2)}}+\ldots+\dfrac{\lambda_n{}^i\,d\lambda_n}{\sqrt{f(\lambda_n)}}=0,\\ \qquad\qquad\qquad\qquad (i=0,1,\ldots n-2)\\ \text{with the equation}\\ \dfrac{\lambda_1{}^{n-1}d\lambda_1}{\sqrt{f(\lambda_1)}}+\dfrac{\lambda_2{}^{n-1}d\lambda_2}{\sqrt{f(\lambda_2)}}+\ldots+\dfrac{\lambda_n{}^{n-1}d\lambda_n}{\sqrt{f(\lambda_n)}}=dt;\end{array}\right.$$

where $f(\lambda)$ is an integral function of the $2n-1$th degree in λ.

For brevity let $\mathrm{N}_\kappa=(\lambda_\kappa-\lambda_1)(\lambda_\kappa-\lambda_2)\ldots(\lambda_\kappa-\lambda_n)$, where the vanishing factor $\lambda_\kappa-\lambda_\kappa$ is omitted;

and $y=\sqrt{(m-\lambda_1)(m-\lambda_2)\ldots(m-\lambda_n)}$,
where $m-\lambda$ is any factor of the function $f(\lambda)$.

The following lemma is next proved: If $\psi(\lambda)$ is a rational integral function of the $2n-2th$ degree in λ, then

$$\sum_{\kappa=1}^{\kappa=n}\frac{\partial}{\partial\lambda_\kappa}\left(\frac{\psi(\lambda_\kappa)}{\mathrm{N}_\kappa{}^2}\right)=0.$$

Making use of this lemma, Jacobi found an algebraic integral of the system (Σ''.) in the form

$$y\left(\frac{\sqrt{f(\lambda_1)}}{(m-\lambda_1)\mathrm{N}_1}+\frac{\sqrt{f(\lambda_2)}}{(m-\lambda_2)\mathrm{N}_2}+\ldots+\frac{\sqrt{f(\lambda_n)}}{(m-\lambda_n)\mathrm{N}_n}\right)=\text{Const.}$$

Corresponding to the $2n-1$ factors $m-\lambda$ of the function $f(\lambda)$, there are $2n-1$ integrals of the form just written, of which $n-1$ are sufficient to give the algebraic relations between the n variables $\lambda_1, \lambda_2, \ldots \lambda_n$.

Haedenkamp (Crelle, bd. xxv. p. 178), specialised the general case, and found by geometric considerations the two complete algebraic integrals of the system (σ.) above.

(27) In each of the $n-1$ integrals derived by Richelot appear two roots of the equation $f(x)=0$, while in Jacobi's solutions there is found only one; and if imaginary roots enter $f(x)$, the integrals found in both of the methods just given have imaginary forms.

Richelot (Crelle, bd. xxv. p. 97) found another method of solution which also depends upon two roots of the equation $f(x)=0$, but has the property of remaining real when for these two roots any two conjugate roots are substituted. He succeeded further in finding a system of $n-1$

solutions of the system (Σ'.), which contain none of the roots of the equation $f(x) = 0$, or presupposes them in any manner. This more general solution is an extension of Jacobi's method, which was effected by the consideration of mechanical problems (art. 24) and throws new light upon Abel's theorem, of which some fundamental forms are derived through suitable integration.

Writing $F(x) = (x - x_1)(x - x_2) \ldots (x - x_n)$, Richelot found as an integral of Σ'.

$$\text{Const.} = F(a)\left\{\frac{\sqrt{f(x_1)}}{(x-x_1)\,F'(x_1)} + \ldots + \frac{\sqrt{f(x_n)}}{(x-x_n)\,F'(x_n)}\right\}^2 - \frac{f(a)}{F(a)} - A_{2n}F(a),$$

in which $f(x) = A_0 + A_1x + \ldots + A_{2n}x^{2n}$, and a denotes any arbitrary integer.

Let a take $n - 1$ different values a_1, a_2, a_{n-1}, and we have a complete system of $n-1$ solutions of the equations (Σ'.) Through suitable integrations of (Σ'.) different forms of Abel's theorem are derived in accordance with Jacobi's suggestions in art. 24.

(28) Jacobi (Crelle, bd. xxxii. p. 220) found that the $n - 1$ algebraic equations through which the system (Σ'.) was integrable consist of one equation of the second degree in a_1 and a_2 (where a_1 denotes the *sum* of the quantities $x_1, x_2, \ldots x_n$, a_2 the sum of these quantities taken two at a time, a_3 the sum taken three at a time, etc.), and of $n - 2$ equations by means of which $a_3, \ldots a_n$ are linearly expressed in terms of a_1 and a_2; and further, that between any two of the quantities a there exists a quadratic, and between any three a linear relation (*cf.* also Weierstrass, 'Math. Werke,' bd. i. p. 267).

Jacobi further showed that if we write

$$\begin{aligned} f(x) = &(bx^n + b_1x^{n-1} + b_2x^{n-2} + \ldots + b_n)^2 \\ &+ (cx^n + c_1x^{n-1} + c_2x^{n-2} + \ldots + c_n)^2 \\ &- (ax^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_n)^2, \end{aligned}$$

the differential equations (Σ'.) are completely integrated, if for $x_1, x_2, \ldots x_n$ are written the roots of the equation

$$\begin{aligned} &x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_n \\ &- (bx + b_1x^{n-1} + b_2x^{n-2} + \ldots + b_n)\cos\phi \\ &+ (cx^n + c_1x^{n-1} + c_2x^{n-2} + \ldots + c_n)\sin\phi, \end{aligned}$$

where ϕ denotes a variable angle.

See also Brioschi (Crelle, bd. lv. p. 56); and Cayley ('Camb. and Dubl. Math. Journ.' vol. iii. 1848, p. 116); 'Math. Papers,' vol. i. p. 366.

(29) *Reduction and Transformation of hyperelliptic integrals.*—We noted Landen's substitutions for the elliptic integrals in art. 8.

Legendre, in the thirty-second chapter of the 'Traité des fonctions elliptiques,' t. i. p. 254, showed in general how to reduce the integrals

$$\int \frac{P\,dx}{\sqrt{\beta + \gamma x^2 + \delta x^4 + \gamma x^6 + \beta x^8}},$$

where P denotes a rational function in x, to elliptic integrals.

In this connection we note a paper by Richelot, 'Ueber die Reduction des Integrales $\int \frac{f(x)dx}{\sqrt{\pm(1-x^8)}}$ auf elliptische Integrale,' Crelle, bd. xxxii. p. 213.

In the third supplement of the 'Traité des fonctions elliptiques,' p. 207, Legendre investigated certain special forms of Abelian integrals as $\int \frac{dx}{\sqrt{1 \pm x^5}}$, and calculated the values of such integrals with fixed limits: on p. 333 (*loc. cit.*), by making use of certain substitutions, he showed that the integral $\int_0^x \frac{dx}{\sqrt{x(1-x^2)(1-\kappa^2 x^2)}}$ could always be reduced to two elliptic integrals of the first kind that have the same amplitude, and whose moduli are the complements of each other (*cf.* a memoir by Catalan, that was crowned by the Academy of Brussels, 'Mém. couronnés par l'Acad. Royale de Brux.' xiv. 2nde partie, p. 2).

Jacobi (Crelle, bd. viii. p. 416) extended this theorem to the integrals $\int \frac{xdx}{\sqrt{(x+x^2)(1-\kappa^2 x^2)}}$, and to integrals of the more general form

$$\int \frac{dx}{\sqrt{\mathrm{R}(x)}} \text{ and } \int \frac{xdx}{\sqrt{\mathrm{R}(x)}},$$

where $\mathrm{R}(x) = x(1-x)(1-\kappa\lambda x)(1+\kappa x)(1+\lambda x)$.

He showed that such integrals may be always expressed as the sum of two elliptic integrals of the first kind which have the same amplitude, but in general different moduli. See also Gauss, 'Determinatio attractionis, quam in punctum quodvis positionis datae exercet planeta,' &c. ('Werke,' iii. p. 333).

More recent examples[1] of similar reductions are given by Hermite ('Ann. Soc. Scient. Brux.' I., B, p. 1, 'Comptes Rendus,' t. xl. 1855); John C. Mallet ('Trans. of Dublin,' 1874) (he extends the theorems of Jacobi to hyperelliptic integrals of any kind); J. C. Mallet (Crelle, bd. lxxvi. p. 79, and bd. lxxix. p. 176); Cayley ('Compt. Rend.' t. lxxxv. pp. 265, 373, 426, 472).

(30) Richelot (Crelle, bd. xii. p. 181) shows that integrals of the form

$$\text{(I.)} \qquad \int \frac{\mathrm{F}(x)dx}{\sqrt{(\mathrm{A}+\mathrm{B}x+\mathrm{C}x^2)(\mathrm{A}_1+\mathrm{B}_1x+\mathrm{C}_1x)(\mathrm{A}_2+\mathrm{B}_2x+\mathrm{C}_2x^2)}},$$

[1] We mention in passing Gordan, 'Ueber die Invarianten binärer Formen höheren Transformationen' (Crelle, bd. lxxi. p. 164); Arondhold, 'Integration irrationaler Differentiale' (Crelle, bd. lxi. p. 95). In this paper extensive use is made of invariants. Brioschi (*Compt. Rend.* t. lvi. and t. lix.) bases this theory of the reduction of integrals $\int \mathrm{F}(x,y)dx$ upon the theory of the covariants of the ternary form. See also Brioschi (*Compt. Rend.* lxxxv. p. 708, 1877); Königsberger (Crelle, bd. lxiv. p. 17; bd. lxv. p. 335; bd. lxvii. p. 97; bd. lxvii. p. 56; bd. lxxxv. p. 273; bd. lxxxix. p. 89; *Math. Ann.* bd. xv. p. 174); Bolza (*Math. Ann.* bd. xxviii. p. 447). A somewhat extended account of the reduction of hyperelliptic integrals, including many of the more recent investigations, is found in Enneper's *Elliptische Functionen*, p. 501 *et seq.*

where $F(x)$ denotes a rational function in x, and where the factors in the denominator are resolvable into real linear factors, may be reduced by means of twelve substitutions of the form $x=\dfrac{a+bz^2}{c+dz^2}$ into an aggregate of integrals

$$\int_0^z \frac{\psi(z^2)dz}{\sqrt{(1-z^2)(1-\kappa^2z^2)(1-\lambda^2z^2)(1-\mu^2z^2)}},$$

where $\phi\ (z^2)$ is a rational function in z^2, z^2 being in value situated between 0 and 1, as are also the quantities κ^2, λ^2 and μ^2.

Richelot further proved that, whatever the degree of the function under the square-root sign, provided it consist of linear real factors, integrals corresponding to (I.) may be reduced to a form similar to that just written.[1]

He further divides these integrals into the three principal kinds, and by means of Abel's theorem considers the peculiar properties of the respective kinds. By making use of irrational substitutions which depend upon a quadratic equation, he finds that integrals of the form

$$\int \frac{(M+Nz^2)dz}{\sqrt{(1-z^2)(1-\kappa^2z^2)(1-\lambda^2z^2)(1-\mu^2z^2)}}$$

may be reduced to the same form

$$\int \frac{(M_1+N_1y^2)dy}{\sqrt{(1-y^2)(1-\kappa'^2y^2)(1-\lambda'^2z^2)(1-\mu'^2z^2)}},$$

where the moduli are either greater or less than the old moduli. By repetition of this procedure the moduli rapidly approach zero or unity (*cf.* art. 8).

(31) In a later paper Richelot (Crelle, bd. xvi. p. 221) reduces integrals of the form $\displaystyle\int_0^\infty \frac{dx}{\sqrt{1+x^5}}$ to $\displaystyle\frac{1}{2}\int_0^1 \frac{2dz}{\sqrt{(1-z_{\prime}(1-\cos^2\frac{\pi}{10}z^2)(1-\cos^2\frac{3\pi}{10}z^2)}}$ by means of the transformations $x=\dfrac{1+t}{1-t}$ where $t=\pm\sqrt{1-z^2}$.

Making use of a substitution that was suggested by Jacobi,

$$2y=\sqrt{a+bz+cz^2}\pm\sqrt{a-bz+cz^2},$$

he shows that the sum and the difference of the integrals

$$\int \frac{dx}{\sqrt{(a+bx+cx^2)(x^2+d)(x^2+e)}} \text{ and } \frac{dx}{\sqrt{(a-bx+cx^2)(x^2+d)(x^2+e)}}$$

may be expressed through *one* Abelian integral. The second part of this memoir is devoted to the numerical calculation of hyperelliptic integrals of the first order.

In the posthumous writings of Jacobi a method is given whereby the

[1] *Cf.* Jacobi, *Gesam. Werke*, bd. ii. p. 38. These integrals may be expanded in converging series according to sines or cosines of multiples of the same angle.

hyperelliptic integrals of the first order may be reduced into canonical forms by means of certain substitutions, even when the factors of the function under the square-root sign in the denominator of the integrand are not all real. Jacobi also avoids the imaginary arguments introduced by Richelot through the application of the substitution $2y=\sqrt{a+bz+cz^2}\pm\sqrt{a-bz+cz^2}$, and which Richelot again reduced to real arguments by means of Abel's theorem. When the degree of the function under the root sign is greater than the sixth, and when this function contains imaginary factors, Jacobi asserts that no one has found the substitutions by which the reduction may be performed. At the close of this article Jacobi discusses Euler's addition-theorem from a more general standpoint than that taken by Lagrange (art. 7).

(32) *Addition-theorems for hyperelliptic integrals.*—Jacobi (Crelle, bd. xxx. p. 121) derived an interesting form of the addition-theorem for hyperelliptic integrals of the second and third kinds. Let R be a given integral function of the $2n$th degree in x

$$\mathrm{R}=a_1x^{2n}+a_2x^{2n-1}+\ .\ .\ .\ +1,$$

and V an integral function of the nth degree with unity as coefficient of highest power of x; further, let a be a constant and

$$(1)\quad x\mathrm{V}^2+a^2\mathrm{R}=(x-x_1)(x-x_2)\ .\ .\ .\ (x-x_{2n+1}) \\ =x^{2n+1}+a_1x^{2n}+a_2x^{2n-1}+\ .\ .\ .\ +a_{2n+1}\,;$$

then it may be proved that[1]

$$(\mathrm{I.})\quad \sum_{i=1}^{i=2n+1}\int\frac{x_i^m dx_i}{\sqrt{x_i\mathrm{R}(x_i)}}=0,$$

where m takes any of the values $0, 1, \ .\ .\ .\ n-1$, and where the upper and lower limits of the integrals are two systems of roots of two equations of the form (1), in which a and the coefficients of V have different values, while R remains the same.

Further, we may deduce the following expressions

$$(\mathrm{II.})\quad \sum_{i=1}^{i=2n+1}\int\frac{x_i^{n+\kappa} dx_i}{\sqrt{x_i\mathrm{R}(x_i)}}=\Lambda_\kappa,$$

where Λ_κ ($\kappa=0, 1, \ .\ .\ .\ n+1$) are algebraic functions of $a, a_1, a_2, \ .\ .\ .\ a_{2n+1}$. Jacobi gives a rule by which those functions are easily determined.

Jacobi makes the theorem above more general by the introduction of a new variable x_{2n+2}, and the formation of new formulæ

$$(\mathrm{III.})\quad \sum_{i=1}^{i=2n+2}\int\frac{x_i^{n+\kappa} dx_i}{\sqrt{x_i\mathrm{R}(x_i)}}=\Lambda_\kappa,$$

where the quantities $a, a_1, \ .\ .\ .\ a_{2n+1}, a_{2n+2}$ are now determined through an equation corresponding to (1)

$$(x-x_1)(x-x_2)\ .\ .\ .\ (x-x_{2n+2})=x^{2n+2}+a_1x^{2n+1}+a_2x^{2n}+\ .\ .\ .\ +a_{2n+2}.$$

For the integrals of the third kind Jacobi proves the following theorem:—

By means of $n+2$ given quantities $x_1, x_2, \ .\ .\ .\ x_{n+1}, a$, let three

[1] See Abel, *Œuvres*, t. i. p. 444.

systems of n quantities $w_1, w_2, \ldots w_n$; $y_1, y_2, \ldots y_n$; $z_1, z_2 \ldots z_n$ be determined through the three systems of n transcendental equations

$$\sum_{i=1}^{i=n}\int\frac{w_i^m dw_i}{\sqrt{w_i \mathrm{R}(w_i)}}=\sum_{i=1}^{i=n+1}\int\frac{x_i^m dx_i}{\sqrt{x_i \mathrm{R}(x_i)}}.$$

$$\sum_{i=1}^{i=n}\int\frac{y_i^n dy_i}{\sqrt{y_i \mathrm{R}(w_i)}}=\sum_{i=1}^{i=n+1}\int\frac{x_i^m dx_i}{\sqrt{x_i \mathrm{R}(x_i)}}+\int\frac{a^m da}{\sqrt{a\mathrm{R}(a)}},$$

$$\sum_{i=1}^{i=n}\int\frac{z_i^m dz_i}{\sqrt{z_i \mathrm{R}(z_i)}}=\sum_{i=1}^{i=n+1}\int\frac{x_i^m dx_i}{\sqrt{x\,\mathrm{R}(x_i)}}-\int\frac{a^m da}{\sqrt{a\mathrm{R}(a)}},$$

$$(m=0,\ 1,\ \ldots\ n-1)$$

in which $\mathrm{R}(x)$ is a given function of x of the $2n$th degree; then there exists among the integrals of the third kind the following equation:—

$$\text{(IV.)}\quad \sum_{i=1}^{i=n}\int\frac{dw_i}{(a-w_i)\sqrt{w_i \mathrm{R}(w_i)}}=\sum_{i=1}^{i=n+1}\int\frac{dx_i}{(a-x_i)\sqrt{x_i \mathrm{R}(x_i)}}$$

$$-\frac{1}{\sqrt{a\mathrm{R}(a)}}\log\frac{1+(-1)^n\sqrt{\dfrac{x_1x_2\ldots x_{n+1}}{ay_1y_2\ldots y_n}}}{1+(-1)^n\sqrt{\dfrac{x_1x_2\ldots x_{n+1}}{az_1, z_2\ldots z_n}}}.$$

When n is made unity in the above formulæ, they reduce to Legendre's form of the addition-theorems for elliptic functions.[1] See Jacobi, 'Extrait d'une lettre addressée à M. Hermite' (Jacobi's 'Werke,' ii. p. 120).

(33) *Interchange of parameter and argument of the integrals of the third kind.*—Legendre discovered this remarkable property of elliptic integrals, and derived other formulæ in the same connection. ('Ex. de Calc. Int.' t. i. p. 134 *et seq.*) The results of Legendre are implicitly contained in the following formula, due to Abel ('Œuvres,' t. ii. p. 43):—

$$\sqrt{\theta(a)}\int\frac{dx}{(x-a)\sqrt{\phi(x)}}-\sqrt{\theta(x)}\int\frac{da}{(a-x)\sqrt{\phi(a)}}$$

$$=\sum\tfrac{1}{2}(n-m)\,a_{m+n+2}\int\frac{x^n dx}{\sqrt{\phi(x)}}\int\frac{a^m da}{\sqrt{\phi(a)}},$$

where $\phi(x)$ is any integral function of x, a_{m+n+2} are constants, and m,n integers. Jacobi (Crelle, bd. xxxii, p. 185; 'Werke,' bd. ii. p. 123) obtained the analogous formula. Let $f(x)$ be a rational integral function of x, and $f_1(x)$ and $f_2(x)$ any two rational integrals of x, whose sum

$$f_1(x)+f_2(x)=\frac{df(x)}{dx};$$

[1] In this connection see Heine (Crelle, bd. lxi. p. 276); Schumann (*Math. Ann.* bd. vii. p. 623); Scheibner (*Math. Ann.* bd. xxxiv. p. 473.) We mention here a paper by Serret, 'Mémoire sur la représentation géométrique des fonctions elliptiques et ultra-elliptiques' (*Liouv. Journ.* t. x. pp. 257, 286, 351 and 421). Liouville (*Compt. Rend.* xxi. p. 1,255, or *Liouv. Journ.* t. x. p. 456) gives a method of representing elliptic and hyperelliptic curves. See Ellis' report, p. 72.

further write

$$\frac{d\log\phi(x)}{dx}=\frac{f_1(x)}{f(x)},\quad \frac{d\log\psi(x)}{dx}=\frac{f_2(x)}{f(x)},$$

then

$$\phi(a)\int\frac{dx}{(x-a)\,\phi(x)}-\psi(x)\int\frac{da}{(a-x)\,\psi(a)}$$

is equal to an aggregate of products of the form

$$C_{m,n}\int\frac{a^m da}{\psi(a)}\int\frac{x^n dx}{\phi(x)},$$

where m and n are integers, and the quantities $C_{m,n}$ are constants.

By making use of certain theorems from the theory of linear differential equations, Abel and Jacobi extended the above results. Formulæ are derived in which the products of the sums of n such integrals remain unchanged when the argument and parameter are interchanged; and by means of these formulæ n^2 integrals may be linearly expressed through n^2 other integrals, in which the parameter and argument have been interchanged; and *vice versâ*, these n^2 integrals may in turn be expressed linearly through the first n^2 integrals. See in this connection Clebsch and Gordan, 'Theorie der Abelschen Functionen,' p. 114, where some interesting consequences are deduced.[1]

(34) Abel, 'Sur l'intégration de la formule différentielle $\frac{\rho\,dx}{\sqrt{R}}$, R et ρ étant les fonctions entières' ('Œuvres,' t. i. p. 104), gave the conditions under which the integrals $\int\frac{\rho\,dx}{\sqrt{R}}$ may be expressed through functions of the form $\log\frac{p+q\sqrt{R}}{p-q\sqrt{R}}$, where p and q are integral functions.[2] In another memoir, published after his death ('Œuvres,' t. ii. p. 87), the general problem is solved, when may an elliptic integral be reduced to algebraic-logarithmic functions? Weierstrass ('Math. Werke,' bd. i. p. 227) says that the general problem of integrating an algebraic differential by means of logarithms, in so far as this is possible, was first proposed by Abel, who had arrived at very important results, as is seen from a letter written to Legendre ('Œuvres,' t. ii. p. 271), and it is very probable that just these investigations led him to his celebrated theorem.

Abel ('Œuvres,' t. i. p. 549) derived the more general theorem relative to the form which one must give to the integral of any algebraic function when it is possible to express this integral by means of algebraic and logarithmic functions and elliptic integrals:

Let $y_1, y_2, \ldots y_\mu$ be algebraic functions of $x_1, x_2, \ldots x_\mu$, and let the x's be connected by any number of algebraic equations.

[1] *Cf.* also Weierstrass, *Werke*, bd. i. p. 113, where the source of the property of interchange of parameter and argument is revealed; Frobenius (Crelle, bd. lxxiii. p. 93).

[2] *Cf.* papers by Tschebyscheff (*Liouv. Journ.* 2nde série, t. ii. p. 1); Pick (*Sitzungsb. der kaiserl. Akad. der Wissenschaften in Wien*, 1882, p. 643); Plana (Crelle, bd. xxxvi. p. 1).

If any integral of the form

$$\int (y_1 dx_1 + y_2 dx_2 + \ldots + y_\mu dx_\mu)$$

is expressible in algebraic and logarithmic functions and elliptic integrals in such a way that

$$\int (y_1 dx_1 + y_2 dx_2 + \ldots + y_\mu dx_\mu) = u + A_1 \log v_1 + A_2 \log v_2 + \ldots + A_\nu \log v_\nu$$
$$+ a_1 \psi_1(t_1) + a_2 \psi_2(t_2) + \ldots + a_n \psi_n(t_n),$$

where $A_1, A_2, \ldots, a_1, a_2, \ldots$ are constants, $u, v_1, v_2, \ldots t_1, t_2, \ldots$ are algebraic functions of $x_1, x_2, \ldots$ and $\psi_1, \psi_2, \ldots$ are any elliptic integrals of the three kinds with any moduli and parameters, then Abel proved that this integral may be always expressed in the form :

$$\delta \int (y_1 dx_1 + y_2 dx_2 + \ldots y^\mu dx_\mu) = r + A' \log \rho' + A'' \log \rho'' + \ldots + A^{(\kappa)} \log \rho^{(\kappa)}$$
$$+ a_1 \psi_1(\theta_1) + a_2 \psi_2(\theta_2) + \ldots + a_n \psi_n(\theta_n),$$

where δ is an integer, $a_1, a_2, \ldots a_n$ are the same as in the preceding expression ; $A', A'' \ldots A^{(n)}$ are constants ; $\theta_1, \Delta_1(\theta_1), \theta_2, \Delta_2(\theta_2) \ldots \theta_n, \Delta_n(\theta_n)$; $r, \rho', \rho'', \ldots \rho^{(\kappa)}$ are rational functions [1] of the quantities $x_1, x_2, \ldots x_\mu$; $y_1, y_2, \ldots y_\mu$.

Abel remarks (p. 550) that this theorem is not only fundamental in all that concerns the application of algebraic and logarithmic functions and elliptic integrals to the theory of the integration of *algebraic* differentials, but it includes all the possible reductions of the integrals of algebraic formulæ by the aid of algebraic and logarithmic functions.

As a corollary is the following theorem : If $\int \frac{\rho dx}{\Delta(x, c)}$, where ρ is any rational function of x, and $\Delta(x,c)$ denotes $\pm\sqrt{(1-x^2)(1-c^2x^2)}$, is expressible by algebraic and logarithmic functions and elliptic integrals, then we may always suppose that

$$\int \frac{\rho dx}{\Delta(x, c)} = p\Delta(x, c) + a\psi(y) + a'\psi_1(y_1) + a''\psi_2(y_2) + \ldots$$
$$+ A_1 \log \frac{q_1 + q_1'\Delta(x, c)}{q_1 - q_1'\Delta(x, c)} + A_2 \log \frac{q_2 + q_2'\Delta(x, c)}{q_2 - q_2'\Delta(x, c)} + \ldots,$$

where all the quantities $p, q_1, q_2, \ldots q_1', q_2', \ldots y, y_1, y_2, \ldots$ are rational functions of x.

From this may be derived a complete solution of the equation

$$\frac{dy}{\Delta(y, c)} = \epsilon \frac{dx}{\Delta(x, c')}$$

where ϵ is a constant, and whence also the general transformation of elliptic integrals of the first kind.

(35) Similar problems were discussed by Liouville [2] ('Mémoires des Savants Étrangers,' t. v. pp. 76 and 103) before he had seen the methods used by Abel. Liouville says that the problems proposed by him do not differ in their origin from those enunciated by Lagrange in the 'Théorie

[1] $\psi_m(x) = \int \frac{\theta' dx}{\Delta_m(x)}$, when θ' denotes any rational function of x, and $\Delta_m(x) = \pm\sqrt{(1-x^2)(1-c_m^2 x^2)}$.

[2] See Poisson's report on these memoirs in Crelle, bd. xii. p. 342, and the note appended by Liouville; also Jürgensen (Crelle, bd. xxiii. p. 129).

analytique des Probabilités,' viz. that the integrals of differential functions cannot contain other radical quantities than those that enter these functions, theorems which were known to the first inventors of analysis (see Leibnitz, 'Act. erud. Lips.'). In the first of the memoirs mentioned above Liouville proposes the problem of finding the form of the integral $\int y dx$, when this integral may be expressed algebraically, where y and x are connected by an algebraic equation

$$y^{\mu}-\mathrm{L}y^{\mu-1}-\ldots-\mathrm{M}y-\mathrm{N}=0,$$

L, M, . . . designating rational functions of x; he shows that the value of such an integral is equal to a certain rational function of x and y. In the discussion of this theorem he classifies functions of one or more variables according to the irrationalities that enter them.[1]

In the second memoir the general theorem which he proposes to demonstrate is: if any algebraic explicit or implicit function y is given, it is always possible to decide if it has or has not for an integral an explicit or implicit algebraic function; and if the question is decided in the affirmative, the same process will give the value $\int y dx$.

He shows that if the integral $\int y dx$ may be expressed algebraically, it has a value of the form:

$$\int y dx=\alpha+\beta y+\gamma y^2+\ldots+\lambda y^{\mu-1},$$

in which $\alpha, \beta, \gamma, \ldots \lambda$ are rational functions of x.

In the twenty-third volume of the 'Journ. de l'École Poly.' p. 37, Liouville finds that if the integral $\int y dx$ is expressible as an explicit finite function of x, it must be of the form:

$$\int y dx=t+\mathrm{A}\log u+\mathrm{B}\log v+\ldots+\mathrm{C}\log w,$$

where A, B, . . . are constants, and $t, u, v, \ldots$ are algebraic functions of x. This theorem is of course contained in the one of Abel in the preceding article. Liouville further shows that if $\int \frac{\mathrm{P}dx}{\sqrt{\mathrm{R}}}$, P and R denoting integral polynomials, cannot be expressed by an algebraic function of x, it cannot be expressed as a finite explicit function of x; from this follows that an elliptic integral of either the first or second kind cannot be expressed as an explicit function of its variable. (See also Liouville, 'Liouv. Journ.' t. v. pp. 34 and 441, where it is proved that the same integrals, considered as functions of their modulus, cannot be expressed in finite form.[2])

(36) Jacobi ('De functionibus duarum variabilium quadrupliciter periodicis,' Crelle, bd. xiii. p. 55; 'Werke,' bd. ii. p. 25) proved that any one-valued function of one variable cannot have more than two independent periods, and that the ratio of these two periods cannot be a real quantity and is irrational.

[1] See also two memoirs by Liouville, 'Sur la Classification des Transcendantes' (*Liouv. Journ.* t. ii. p. 56, and t. iii. p. 523); and Poisson (Crelle, bd. xii. p. 89, and bd. xiii. p. 93)

[2] Cf. *Liouv. Journ. de l'École Poly.*, t. xiv. p. 137; and Ellis, p. 70.

Making use of Richelot's transformation, Jacobi wrote the general integral under consideration in the form :

$$\text{(A.)} \qquad \int^x \frac{(a+\beta x)dx}{\sqrt{x(1-x)(1-\kappa^2x)(1-\lambda^2x)(1-\mu^2x)}}.$$

He distinguished the values of this integral within the six intervals :

$$(1)\ -\infty \ldots 0, \quad (2)\ 0 \ldots 1, \quad (3)\ 1 \ldots \frac{1}{\kappa^2},$$

$$(4)\ \frac{1}{\kappa^2} \ldots \frac{1}{\lambda^2}, \quad (5)\ \frac{1}{\lambda^2} \ldots \frac{1}{\mu^2}, \quad (6)\ \frac{1}{\mu^2} \ldots \infty.$$

When the upper limit x in formula (A.) is considered as a function of u and written $x=\lambda(u)$, this function behaves like a periodic function within each of these intervals, and therefore seems to have six periods, of which four are independent. Further, this function remains unchanged when u assumes any real or imaginary value, or better expressed, of the values which u may take, there are always those which differ from any real or imaginary quantity by less than any assignable quantity, however small.

Jacobi found in this a troublesome paradox, which, however, he had already in a measure overcome by means of Abel's theorem (see following article).

Jacobi next proved that if a given function of two variables is an one-valued function of these variables, it is impossible for this function to have more than four independent periods.[1]

(37) *The inverse functions.*—Corresponding to the function $x=\text{sn}\ u$ (art. 9), if we try to introduce into analysis a transcendent $x=\lambda(u)$, where

$$\text{(I.)}\ u=\int_0^x \frac{dx}{\sqrt{X}}=\Pi(x),$$

X being a rational integral function of the fifth or sixth degree in x, then there is no analogy between this function and the elliptic function $x=\text{sn}\ u$, since such a function, as seen above, has for every value of u not only many values, but is wholly indeterminate,[2] if for the definition of the integral we consider only the limits and not the paths which the variable describes from one limit to the other. Hence, when we consider the integral (I.) by itself, its inversion does not give useful results.

The close connection between the integral $\Pi(x)$ and the integral

$$\text{(II.)}\ \Pi_1(x)=\int_0^x \frac{xdx}{\sqrt{X}}$$

was seen in art. 23.

Jacobi conceived the very fortunate idea of inverting these integrals

[1] The more general theorem that *a one-valued function of* n *variables cannot have more than* 2n *independent periods* was proved much later by Riemann (Crelle, bd. lxxi. p. 197). See also Weierstrass (*Monatsb. der Akad. der Wiss. zu Berlin*, 1876, p. 680; *Functionenlehre*, p. 166).

[2] *Cf.* Jacobi (Crelle, bd. ix. p. 394; *Werke*, bd. ii. pp. 7 and 516).

by connecting two integrals u and v with the variables x_1 and x_2 in the following equations :

$$(1)\ u=\int_0^{x_1}\frac{dx}{\sqrt{X}}+\int_0^{x_2}\frac{dx}{\sqrt{X}}=\Pi(x_1)+\Pi(x_2),$$

$$(2)\ v=\int_0^{x_1}\frac{xdx}{\sqrt{X}}+\int_0^{x_2}\frac{xdx}{\sqrt{X}}=\Pi_1(x_1)+\Pi_1(x_2).$$

In these two equations, when u is given, the upper limits x_1 and x_2 are not yet determined, there being two of them ; so that we may regard u and v as independent of each other. This we cannot do when we consider the integrals (I.) and (II.) separately ; for if x was determinate for a given value of u in (I.), then it would be determined in (II.), and therefore (II.) would be determined.

When u and v are given, the totality of the upper limits (that is, of x_1 and x_2) is known ; but these quantities may be permuted, so that x_1+x_2 and $x_1.x_2$ are definitely determined when u and v are given, and may be expressed as the roots of a quadratic equation $Ax^2+Bx+C=0$, where $x_1+x_2=-\frac{B}{A}=\phi(u,v)$, and $x_1.x_2=\frac{C}{A}=\psi(u,v)$. A, B, and C are functions of u and v, which have definite finite values for all finite values, real or imaginary, of the two arguments u and v ; and the functions $\phi(u,v)$ and $\psi(u,v)$ have with reference to the arguments u and v four simultaneous independent periods.

Let the values of x_1 and x_2, determined from the quadratic equation above, be $x_1=\lambda(u,v)$, $x_2=\lambda_1(u,v)$.

In these functions it is seen that when one of the arguments goes to infinity, the other becomes indeterminate, and when one of the arguments changes by a constant quantity the other argument is also changed, so that both arguments undergo an alteration at the same time, and the period of one argument is determined by the period of the other ; this is the characteristic property of the periodicity.

(38) The functions $\lambda(u,v)$ and $\lambda_1(u,v)$ are analogous to the elliptic and trigonometric functions, and may be algebraically expressed in terms of functions that contain only one variable.[1]

For let x_1^0 and x_2^0 be the values of x_1 and x_2 when we put $v=0$, and $x_1^{(0)}$ and $x_2^{(0)}$ the values of these variables when $u=0$.

Then from equation (1) and (2) above

$$\Pi(x_1^0)+\Pi(x_2^0)=u\ ;\ \Pi_1(x_1^0)+\Pi_1(x_2^0)=0,$$
$$\Pi(x_1^{(0)})+\Pi(x_2^{(0)})=0\ ;\ \Pi_1(x_1^{(0)})+\Pi_1(x_2^{(0)})=v.$$

Hence

$$\Pi(x_1^0)+\Pi(x_2^0)+\Pi(x_1^{(0)})+\Pi(x_2^{(0)})=u,$$
$$\Pi_1(x_1^0)+\Pi_1(x_2^0)+\Pi_1(x_1^{(0)})+\Pi_1(x_2^{(0)})=v.$$

Owing to Abel's theorem, the two quantities x_1 and x_2 may be algebraically expressed as functions of x_1^0, x_2^0, $x_1^{(0)}$, and $x_2^{(0)}$ in such a way that

$$\Pi(x_1^0)+\Pi(x_2^0)+\Pi(x_1^{(0)})+\Pi(x_2^{(0)})=\Pi(x_1)+\Pi(x_2)=u,$$
$$\Pi_1(x_1^0)+\Pi_1(x_2^0)+\Pi_1(x_1^{(0)})+\Pi_1(x_2^{(0)})=\Pi_1(x_1)+\Pi_1(x_2)=v$$

[1] See Jacobi (Crelle, bd. xxx. p. 183 ; *Werke*, bd. ii. p. 85).

exist simultaneously; so that x_1 and x_2 are algebraic functions of the four quantities x_1^0, x_2^0, $x_1^{(0)}$, and $x_2^{(0)}$; that is, the functions of two variables $\lambda(u,v)$ and $\lambda_1(u,v)$ may be algebraically expressed in terms of the four quantities of a single variable

$$\lambda(u,0),\ \lambda_1(u,0),$$
$$\lambda(0,v),\ \lambda_1(0,v).$$

Eisenstein (Crelle, bd. xxvii. p. 185) writes as follows regarding the inverse functions: 'Great difficulties are found with the Abelian integrals whose inverse functions have a triple or multiple periodicity. Under the assumption that an integral with definite lower limit may take all possible real and imaginary values for any given value of the variable, the Abelian integral ceases to be a function of its variable. In order to meet these difficulties, for example in the Abelian integrals of the first order, Jacobi considered two such integrals connected by the relations (1) and (2) of the preceding article. But if we grant that the function $\Pi(x_1)$ can have all possible values for any given value of x_1, the function $\Pi(x_2)$ may have the same property for every given value of x_2, and so the sum u may for a greater reason take all possible values for given values of x_1 and x_2. The same is true of v; so that it is not clear how we may speak in this wise of a dependency between u, v, x_1, and x_2.' Eisenstein then proposes, in order to set forth the real nature of these functions after the analogue of the elliptic functions (art. 11), to form the quotients of the quotients of infinite triple products.

Jacobi ('Werke,' bd. ii. p. 86) corrects Eisenstein's objections with the remarks that Eisenstein did not understand the nature of the functions $\lambda(u,v)$, $\lambda_1(u,v)$, his mistake being that he did not sufficiently comprehend the fundamental principle of the co-existence of the periods relative to the two arguments u and v. He then asks if the quotients of quotients are not simply quotients, and points out how Eisenstein has made some fundamental mistakes in the theory of elliptic functions (Crelle, bd. xxvii. pp. 185 and 285).

(39) Hermite (Extrait d'une Lettre à M. Liouville, 'Comp. Rendus,' t. xviii.; 'Liouville's Journ.' t. ix. p. 353) introduces into the analysis of the transcendents of any algebraic differentials the inverse functions of several variables, after the example of that which had been done by Jacobi for the hyperelliptic integrals of the first order.

Using the notation of Abel and of Minding, he takes

$$\chi(y)=p_0+p_1y+p_2y^2+\ .\ .\ .\ +p_{n-1}y^{n-1}+y^n=0,$$

an irreducible algebraic equation, whose coefficients are rational and integral functions of x. The roots of this equation he denotes by y_1, y_2, . . . y_n. He further writes:

$$f(x,y)=t_0+t_1y+\ .\ .\ .\ +t_{n-2}y^{n-2}$$

any rational integral function in x and y, in which the degrees of the x's are subjected to certain restrictions.

Finally, let γ denote the number of arbitrary constants that are contained in the function $f(x,y)$; this function may then take γ different forms, which are represented by

$$f_1(x,y), f_2(x,y), \ .\ .\ .\ f_\gamma(x,y).$$

Designate by x_1, x_2, . . . x_μ. . . μ variables where $\mu>\gamma$ and by $y_{(1)}, y_{(2)}$ . . . $y_{(\mu)}$, irrational functions arbitrarily chosen among the n roots y_1, y_2, . . . y_n.

Then by Abel's theorem we have in algebraic form the complete integrals of the system of equations.

$$\sum_{j=1}^{j=\mu} \int \frac{f_i(x_j, y_{(j)})}{\chi'(y_{(j)})} dx_j = 0,$$

$$(i=1, 2, \ldots \gamma).$$

(40) Hermite then takes for the inverse functions the quantities $x_1, x_2, \ldots x_\gamma$ defined by the γ equations

$$\sum_{j=1}^{j=\mu} \int_0^{x_j} \frac{f_i(x_j, y_{(j)})}{\chi'(y_{(j)})} dx_j = u_i,$$

$$(i=1, 2, \ldots \gamma),$$

and writes

$$x_i = \lambda\,(u_1, u_2, \ldots u_\gamma),$$

$$(i=1, 2, \ldots \gamma).$$

It follows [1] without difficulty that the γ functions

$$\lambda\,(u_1+v_1, u_2+v_2, \ldots u_\gamma+v_\gamma),$$

$$(i=1, 2, \ldots \gamma),$$

are the roots of an algebraic equation of the degree γ, whose coefficients are rational functions of the different functions

$$\lambda_i\,(u_1, u_2, \ldots u_\gamma), \lambda_i\,(v_1, v_2, \ldots v_\gamma),$$

$$(i=1, 2, \ldots \gamma).$$

In the third section of this memoir, Hermite discusses the periodic properties of these functions, and determines their periods.

The theorem relative to the addition of the arguments leads to the expression of the inverse functions in all their generality in terms of the simplest particular functions, in which we may suppose successively that only one argument varies, the others being constant, zero for example (*cf.* art. 38).

As an illustration, we saw in art. 24 that functions connected with the hyperelliptic integrals of the second order arise, in which appear three arguments, $\Pi\,(u, v, w)$, say ; and from Abel's theorem it follows that

$$\Pi\,(u + u' + u'', v + v' + v'', w + w' + w'') = \Pi\,(u, v, w) + \Pi\,(u', v', w') + \Pi\,(u'', v'', w'') + \text{alg. and logarith. function.}$$

Now writing

$$u = 0, v = 0\,;\ u' = 0, w' = 0\,;\ v'' = 0, w'' = 0,$$

we have

$$\Pi\,(u'', v', w) = \Pi\,(0, 0, w) = \Pi\,(0, v', 0) + \Pi\,(u'', 0, 0) + \text{alg. and logarith. function.}$$

At the end of this memoir are found certain theorems relative to the transformation of elliptic integrals (*cf.* Hermite, 'Cours à la Faculté des Sciences de Paris,' 4ème éd., 1891) ; from these theorems formulæ are deduced which set forth in a beautiful manner many problems of trans-

[1] See also Hermite ('Sur la division des fonctions Abéliennes,' *Mémoires des Savants étrangers*, 1848, p. 572); and Richelot (Crelle, bd. xxix. p. 281; and *Liouville's Journ.* 1843, p. 505).

formation, multiplication, and division that are found in Jacobi's 'Fund. Nova.' Among others we may mention a direct method of the transformation of elliptic functions of the third kind, without presupposing, as is done by Jacobi, the formula of the transformation of functions of the second kind.

(41) Jacobi, in the eleventh section of his memoir 'De functionibus duarum variabilium quadrupliciter periodicis,' states without demonstration that if we have

$$x = \lambda(u, v),\ y = \lambda_1(u,v),$$

then the functions

$$x_n = \lambda(nu,nv),\ y_n = \lambda_1(nu,nv)$$

are by Abel's theorem obtained as the roots of a quadratic equation

$$\mathrm{U}x_n^2 + \mathrm{U}'x_n + \mathrm{U}'' = 0,$$

in which U, U′, U″ are rational functions of x, y, $\sqrt{\mathrm{X}}, \sqrt{\mathrm{Y}}$ (see art. 37); and from this it is seen, *vice versâ*, that x and y may be obtained from x_n and y_n by the solution of algebraic equations.

Hermite (Crelle, bd. xxxii. pp. 176 and 277) finds that the coefficients U, U′, and U″ are of the form $\mathrm{P} + \mathrm{Q}\,\Delta(x)\Delta y$, where P and Q are rational functions of x and y, and where

$$\Delta(x) = \sqrt{\mathrm{X}}\ \text{(above)} = \sqrt{x(1-x)(1-\kappa^2x)(1-\lambda^2x)(1-\mu^2x)}.$$

Let $i_1\sqrt{-1}$, i_2, $i_3\sqrt{-1}$, i_4 be the four periods of the integral $\int\frac{(\alpha+\beta x)}{\Delta(x)}dx$, and $i'_1\sqrt{-1}$, i'_2, $i'_3\sqrt{-1}$, i'_4 the corresponding periods of $\int\frac{(\alpha'+\beta' x)}{\Delta(x)}dx$; then the simultaneous roots of the two equations

$$\text{(A.)}\qquad \mathrm{U}x_n^2+\mathrm{U}'x_n+\mathrm{U}''=0,\ \mathrm{U}y_n^2+\mathrm{U}'y_n+\mathrm{U}''=0$$

are expressed by Hermite through the formulæ

$$x=\lambda\left(u+\frac{mi_1\sqrt{-1}+m'i_2+m''i_3\sqrt{-1}+m'''i_4}{n},\right.$$
$$\left.v+\frac{mi'_1\sqrt{-1}+m'i'_2+m''i'_3\sqrt{-1}+m'''i'_4}{n}\right),$$

$$y=\lambda_1\left(u+\frac{mi_1\sqrt{-1}+m'i_2+m''i_3\sqrt{-1}+m'''i_4}{n},\right.$$
$$\left.v+\frac{mi'_1\sqrt{-1}+m'i'_2+m''i'_3\sqrt{-1}+m'''i'_4}{n}\right),$$

where m, m', m'', and m''' may take any of the values $0, 1, \ldots n-1$.

For brevity Hermite writes

$$\mathrm{I}=mi_1\sqrt{-1}+m'i_2+m''i_3\sqrt{-1}+m'''i_4,$$

and

$$\mathrm{I}'=mi'_1\sqrt{-1}+m'i'_2+m''i'_3\sqrt{-1}+m'''i'_4,$$

and by $f(x,y)$ is denoted any rational symmetric function of x and y, and p, q, r, s are used to indicate any four of the roots $x^n=1$.

Hermite next proves that

$$\text{(B.)}\quad \sum_{m'''=0}^{m'''=n-1}\ \sum_{m''=0}^{m''=n-1}\ \sum_{m'=0}^{m'=n-1}\ \sum_{m=0}^{m=n-1} f\left[\lambda\left(u+\frac{\mathrm{I}}{n},\ v+\frac{\mathrm{I}'}{n}\right),\right.$$

$$\left.\lambda_1\left(u+\frac{\mathrm{I}}{n},\ v+\frac{\mathrm{I}'}{n}\right)\right] p^m\, q^{m'}\, r^{m''}\, s^{m'''}$$

$$=\sqrt[n]{\mathrm{A}+\mathrm{B}\Delta(\lambda(nu,\ nv))+\mathrm{C}\Delta(\lambda_1(nu,\ nv))+\mathrm{D}\Delta(\lambda(nu,\ nv))\ \Delta(\lambda_1(nu,\ nv))}$$

where A, B, C, D are rational functions of $\lambda(nu, nv)$ and $\lambda_1(nu, nv)$.

The first member of this equation may be denoted by $\phi\ (u, v)$, and may be expressed rationally in terms of $\lambda\ (u, v)$ and $\lambda_1\ (u, v)$, since, owing to the fundamental properties of the functions λ and λ_1, this is true of each of the terms constituting $\phi\ (u, v)$.

It is easily proved that

$$\phi\left(u+\frac{\kappa i_1\sqrt{-1}+\kappa' i_2+\kappa'' i_3\sqrt{-1}+\kappa''' i_4}{n},\right.$$

$$\left.v+\frac{\kappa i_1'\sqrt{-1}+\kappa' i'_2+\kappa'' i'_3\sqrt{-1}+\kappa''' i'_4}{n}\right)$$

$$=p^{-\kappa}q^{-\kappa'}r^{-\kappa''}s^{-\kappa'''}\phi\,(u, v),$$

whatever be the values of the integers κ, κ', κ'' and κ'''.

The nth power of ϕ is a rational function in $\lambda\ (u, v)$, $\lambda_1\ (u, v)$, which does not change when for these quantities are substituted any two other of the simultaneous roots of the proposed equations. It follows, therefore, from the theory of the symmetric functions of the roots of a system of equations in several unknown quantities, that this function may be rationally determined in the coefficients of the equation (A.); and since any rational function of two roots $\Delta\,(\lambda\ (nu, nv))$, $\Delta\ (\lambda_1\ (nu, nv'))$ may be put under the form

$$\mathrm{A}+\mathrm{B}\Delta\ (\lambda\ (nu, nv))+\mathrm{C}\Delta\ (\lambda_1\ (nu, nv))+\mathrm{D}\Delta\ (\lambda\ (nu, nv))\,\Delta\ (\lambda_1\ (nu, nv)),$$

the theorem is proved.

(42) Hermite says, in continuance of the above discussion, it seems, that the preceding considerations may be extended to the hyperelliptic integrals in general.

For let $\Delta(x)=\sqrt{x(1-x)\,(1-\lambda_1{}^2x)\ \ldots\ (1-\lambda^2{}_{2n+1}x)}$,

$$\theta_\kappa(x)=\alpha_\kappa+\beta_\kappa x+\gamma_\kappa x^2+\ \ldots\ +\eta_\kappa x^n,$$

$$\Phi_\kappa(x)=\int_0^x\frac{\theta_\kappa(x)dx}{\Delta(x)}\,;$$

and write

$$u_i=\Phi_i(x_0)+\Phi_i(x_1)+\Phi_i(x_2)+\ \ldots\ +\Phi_i(x_n),$$

and $x_i=\lambda_i(u_0, u_1, u_2,\ \ldots\ u_n)$,

$$(i=0,\ 1,\ 2,\ \ldots\ n).$$

Then $\Delta(x_i)=\theta_0(x_i)\dfrac{\partial x_i}{\partial u_0}+\theta_1(x_i)\dfrac{\partial x_i}{\partial u_1}+\theta_2(x_i)\dfrac{\partial x_i}{\partial u_2}+\ \ldots\ +\theta_n(x_i)\dfrac{\partial x_i}{\partial u_n}$,

$$(i=0,\ 1,\ 2,\ \ldots\ n),$$

where the partial derivatives may be rationally expressed in terms of the functions λ. Since θ is of the nth degree, it appears that the roots of the equation of the nth degree

$$0=\theta_0(x)\frac{\partial x_i}{\partial u_0}+\theta_1(x)\frac{\partial x_i}{\partial u_1}+\theta_2(x)\frac{\partial x_i}{\partial u_2}+\ \ldots\ +\theta_n(x)\frac{\partial x_i}{\partial u_n}$$

are the n functions $x_0, x_1, \ldots\ x_n$.

In a letter to Liouville (*loc. cit.* p. 361), Hermite states that the representation of these functions is attended with great difficulties.

By supposing successively $f(x, y)=x+y$ and $f(x, y)=x.y$, the preceding theorem will give, expressed by a sum of nth roots, in number n^4-1, the coefficients of an equation of the second degree, whose roots will determine those of the proposed equations. These n^4-1 roots will be expressed rationally in terms of four of them.

Hermite next discusses the division of the periods.

In the second paper mentioned above, Hermite derives *first* certain theorems, from which he deduces, among others, Jacobi's formula for the algebraic expression of sin am (x) by sin am $\left(\frac{x}{\mathrm{M}}\right)$, and Abel's fundamental properties of elliptic functions which relate to the addition of the arguments; other formulæ, which involve Jacobi's H and Θ functions are given.

Applications are then made to functions of two arguments and four periods. Hermite writes the integrals of the third kind in the form

$$\text{(I.)}\quad \int\left\{\left(\frac{\Delta(a)}{x-a}+\frac{\Delta(b)}{x-b}\right)\frac{2dx}{\Delta x}+\left(\frac{\Delta(a)}{y-a}+\frac{\Delta(b)}{y-b}\right)\frac{2dy}{\Delta y}\right\},$$

the integral being subjected to vanish, when $x=0$ and $y=0$. Δx represents the square root of the polynomial $p_1x+p_2x^2+p_3x^3+p_4x^4+p_5x^5$.

After

$$x=\lambda(u,v)\quad y=\lambda_1(u,v)$$
$$a=\lambda(\alpha,\beta)\quad b=\lambda_1(\alpha,\beta)$$

are substituted in (I.), this integral is denoted by $\Pi(u,v,\alpha,\beta)$. When the variables u and v are introduced into the integrals of the second kind

$$\int\left(\frac{x^2dx}{\Delta(x)}+\frac{y^2dy}{\Delta(y)}\right)\text{ and }\int\left(\frac{x^3dx}{\Delta(x)}+\frac{y^3dy}{\Delta(y)}\right),$$

they are first denoted by $(u,v)_1$ and $(u,v)_2$ respectively.

Two new integrals are defined by the relations:

$$\mathrm{E}_1(u,v)=2p_4(u,v)_1+3p_5(u,v)_2\text{ and }\mathrm{E}_2(u,v)=p_5(u,v)_1.$$

The following theorem is then derived

$$\Pi(u,v,\alpha,\beta)-\Pi(\alpha,\beta,u,v)=p_3(\alpha v-\beta u)+\alpha\mathrm{E}_1(u,v)$$
$$+\beta\mathrm{E}_2(u,v)-u\mathrm{E}_1(\alpha,\beta)-v\mathrm{E}_2(\alpha,\beta),$$

a formula in which is seen the law of interchange of parameter and argument (art. 33).

Hermite further defines a function Φ by the relation

$$\Phi(u,v,\alpha,\beta)=\Pi(u,v,\alpha,\beta)+u\mathrm{Z}_1(\alpha,\beta)+v\mathrm{Z}_2(\alpha,\beta)-c(\alpha v-\beta u),$$

where Z_1 and Z_2 are certain functions of E_1 and E_2 respectively, and c is a constant.

Interesting addition-formulæ are derived for the two functions Π and Φ (*cf.* report made by Lamé and Liouville, 'Comp. Rend.' xvii. and 'Liouv. Journ.' t. viii. p. 502).

(43) *The introduction of the theta-function.*—The new functions of four simultaneous periods which Jacobi had discovered were received with great enthusiasm by mathematicians. The Academy of Sciences at Copenhagen wished to see presented the analogous functions that are connected with the integrals of all algebraic functions, to which Abel's

theorem may be applied.[1] The representation of these functions, however, was not forthcoming, and later the solution of this problem was set as a prize question by the Berlin Academy of Sciences.

Abel had shown that the elliptic function $x=\operatorname{sn} u$ could be represented as the quotient of infinite products. Jacobi, with the thought of representing an infinite product by means of a transcendental function, introduced into analysis the so-called *θ-function*, which represents such a product in the form of a power series. Investigating further this transcendent, he discovered its marvellous properties, and made use of it in his further researches in the elliptic functions. Jacobi[2] founded the whole theory of elliptic functions upon this new transcendent, which made these functions remarkably clear and simple, as well as their applications, for example, to rotatory motion, the swing of the pendulum, and innumerable problems of physics and mechanics; also by it the realms of geometry were essentially widened, and many abstract properties of the theory of numbers were revealed in a new light.

Hence it appears that the θ-function showed itself of paramount importance for the study of mathematics during the Jacobian epoch, and as a prototype it served for the future development of the function-theory and of all mathematics.

(44) The elliptic function $x=\operatorname{sn} u$, as shown by Jacobi, may be expressed as the quotient of two θ-functions, where the θ-function may be written in the form

$$\theta(u)=\sum_{m=-\infty}^{m=\infty} e^{m^2\tau+2mu},$$

in which m takes all integral values from $-\infty$ to $+\infty$, u is the variable, and the constant τ is determined from the two periods of the integral

$$u=\int_0^x \frac{dx}{\sqrt{X}},$$

where X is of the fourth degree in x; or, as Jacobi says, τ determines the modulus of the elliptic integral.

(45) *θ-functions of two arguments.*—Goepel,[3] and in an independent manner Rosenhain,[4] generalised the simple θ-function of one variable and formed analogous transcendents, the θ-functions of two variables

$$\theta(u,v)=\sum_{-\infty m,n}^{+\infty} e^{a_1m^2+a_2mn+a_3n^2+2mu+2nv},$$

where here both m and n take all possible integral values from $-\infty$ to $+\infty$, u and v are the variables, and the constants a_1, a_2, and a_3 are determined from the four periods of the integrals

$$\int_0^x \frac{dx}{\sqrt{X}} \text{ and } \int_0^x \frac{xdx}{\sqrt{X}},$$

[1] Jacobi, *Werke*, bd. ii. p. 517.

[2] Jacobi, *Fund. Nova*, p. 45; also *Werke*, bd. i., p. 497. More recently Schellbach has made the θ-function his starting-point in his book, *Die Lehre von elliptischen Integralen und den Theta-Functionen*, Berlin, 1864.

[3] Goepel, *Theoriæ transcendentium Abelianarum primi ordinis adumbratio levis* (Crelle, bd. xxxv. p. 277, 1847).

[4] Rosenhain, *Mémoire sur les fonctions de deux variables à quatre périodes, &c.*, *Mém. des Savants étrangers*, t. xi. p. 361; see also Crelle, bd. xl. p. 319. Further see Jacobi, *Notiz über A. Goepel*, Crelle, bd. xxxv. p. 313.

where X is a rational integral function of the fifth or sixth degree [1] in x. By means of the quotients of two such θ-functions Goepel and Rosenhain showed how to represent the functions $\phi(u,v)$ and $\psi(u,v)$ (art. 37), and thus completely solved the problem of representing the inverse functions of the hyperelliptic integrals of the first order.

The zeros and periodic properties of these two θ-functions, the relations between the squares of such functions and of the constants that enter these relations, the number of independent relations, Goepel's biquadratic relation, the connection between these functions and Kummer's sixteen-nodal quartic surface, and similar questions, are found in Harkness and Morley's 'A Treatise on the Theory of Functions,' p. 341 *et seq.*

(46) Goepel remarked that his investigations could be extended to any number of variables; but in this connection Jacobi showed that there is a troublesome paradox ('Werke,' bd. ii. p. 521; and Weierstrass, 'Werke,' bd. i. p. 142); since, when there are more than two variables, the generalised θ-function contains more essential constants than the hyperelliptic functions with like number of variables.

(47) We must mention next papers by Hermite, 'Sur la théorie de la transformation des fonctions Abéliennes' ('Compt. Rend.' xl. pp. 249, 303, 365, 427, 485, 536, 704, and 784).

Besides the sum and the quotient of x and y (of art. 37), which we saw could be expressed through fractions whose numerator and denominator are functions of the argument u and v, and have unique and finite values for all finite real and imaginary values of these arguments, Goepel and Rosenhain gave in an analogous form the analytical expression of thirteen other functions of u and v, which depend algebraically but in an irrational manner upon the first two.

Hermite [2] designates by $f_1(u,v)$, $f_2(u,v)$, . . . $f_{15}(u,v)$ this complete system of fifteen functions which appear in the study of the integrals

$$(\mathrm{I.})\left\{\begin{aligned} &\int^{x}\frac{dx}{\sqrt{\phi(x)}}+\int_{y_0}^{y}\frac{dx}{\sqrt{\phi(x)}}=u,\\ &\int_{x_0}^{x}\frac{x\,dx}{\sqrt{\phi(x)}}+\int_{y_0}^{y}\frac{y\,dy}{\sqrt{\phi(y)}}=v,\end{aligned}\right.$$

when $\phi(x)$ denotes a polynomial of fifth or sixth degree in x, and which are analogous to the functions $\operatorname{sn} u$, $\operatorname{cn} u$, and $\operatorname{dn} u$ of the elliptic inte-

[1] Cayley ('Memoir on the Single and Double θ-function,' *Phil. Trans.* 1880, pp. 897–1002) treats the whole theory in a manner analogous to that employed by Goepel. In this paper special attention is paid to the relations among the squares of the functions and to the derivation of the biquadratic relation among four of the functions, which is the same as Kummer's sixteen-nodal quartic surface. See also Cayley (Crelle, bd. lxxxiii. pp. 210 and 235; and Forsyth (Biographical Notice on Arthur Cayley, 'Obituary Notices' of the *Proc. Royal Society*, vol. lviii.), and Cayley's *Math. Papers*, vol. viii. p. ix, where other references are given. Other papers on the same subject by Cayley are found in Crelle, bd. lxxxv. lxxxvii. and lxxxviii. Prof. Forsyth, 'Memoir on the Theta-function, particularly those of two Variables' (*Phil. Trans.* 1882, vol. clxxiii. p. 783) follows more closely Rosenhain's paper, and extends it in many directions. *Cf.* also Königsberger (Crelle, bd. lxiv. p. 17; bd. lxxxi. p. 193; and especially bd. lxxxvii. p. 173, where the problem of transformation is discussed fully), and also *Math. Ann.* bd. xv. p. 174.

[2] Hermite, *Sur la théorie de la transformation des fonctions Abéliennes* (*Compt. Rendus*, t. xl. pp. 249, 303, 365, 427, 485, 536, 704, 784).

grals. In a similar manner he denotes by $F_1(u,v)$, $F_2(u,v)$, . . . $F_{15}(u,v)$ the functions of a similar nature to which one would come in taking for point of departure the equations

$$\text{(II.}\quad \left\{ \begin{aligned} &\int_{x_0}^{x} \frac{\alpha+\beta x}{\sqrt{\psi(x)}}dx+\int_{y_0}^{y} \frac{\alpha+\beta y}{\sqrt{\psi(y)}}dy=u, \\ &\int_{x_0}^{x} \frac{\gamma+\delta x}{\sqrt{\psi(x)}}dx+\int_{y_0}^{y} \frac{\gamma+\delta y}{\sqrt{\psi(y)}}dy=v, \end{aligned} \right.$$

where α, β, γ, and δ are constants, and $\psi(x)$ a polynomial of the fifth or sixth degree in x.

Hermite proposes as follows the problem of transformation : The polynomial $\psi(x)$ in (I.) being given, determine the coefficients of $\psi(x)$, and the constants α, β, γ, and δ in such a manner that the fifteen functions $F(u, v)$ be rationally expressed in terms of the fifteen functions $f(u,v)$.

By comparison of the linear relations that must exist among the periods of the $f(u, v)$ functions and the $F(u, v)$ functions, and of the relations that exist among the periods that belong to these respective functions, many remarkable consequences are deduced. In this connection see a letter of Eisenstein to Hermite ('Liouv. Journ.' xvii.) and also Eisenstein, 'Ueber die Vergleichung von solchen ternären quadratischen Formen, welche verschiedene Determinanten haben' ('Sitzungsber. der Berlin. Akad.' June 1852), and Hermite (Crelle, bd. xlvii. p. 343). From these papers is seen the intimate relation that exists between the analytic theory of transformation and the arithmetical theory of quadratic forms.

In the execution of the transformation a system of sixteen θ-functions is introduced, sixteen functions which may be algebraically expressed in terms of any two of them.

Four new functions, Π_0, Π_1, Π_2, and Π_3, are introduced, which may be expressed by an integral homogeneous function of degree κ in four of the θ-functions. The Π-functions contain linearly $\frac{\kappa^2+1}{2}$ constants. There are just enough conditions of the problem to determine these constants. Further, the Π-functions are defined in terms of other Θ-functions. From this follow immediately relations among the quadruply-periodic quotients which arise from the division of two Θ-functions and those which arise from the division of two θ-functions. These last functions may be regarded as representing the more general periodic functions which orginate from the hyperelliptic integrals of the first order, when the arguments x and y have been replaced by others which depend linearly upon them in any manner.

Thus the proposed problem of transformation is solved.[1] On p. 704 of the 'Compt. Rendus,' t. xl., Hermite gives a method of division of the θ-functions, and compares them with Weierstrass' Al-functions of the following article.

Liouville and Hermite made use of the periodic properties of the single θ-functions, and derived for the elliptic functions the results of addition, multiplication, transformation, and division ; and Hermite by direct trans-

[1] *Cf.* Brioschi (*Compt. Rend.* xlvii. p. 310).

formations gained a clearer insight into the properties of the θ-functions of two variables. See Liouville ('Compt. Rendus,' 1851); and Hermite, (Crelle, bd. xxxii. pp. 176 and 277).

(48) As those mathematicians whose works were mentioned in arts. 1–11 laid the foundation for the investigations of Jacobi and Abel, so may we also regard the works that have been reviewed up to the present time as introductory to the works of Weierstrass and Riemann.

The theory of Abelian functions has been so generalised, so widened, by these mathematicians and their followers that we may make the same remark concerning it as Jacobi (in a letter to Crelle, 'Crelle's Journ.' bd. iii. p. 310) made regarding the elliptic functions: 'You see that the theory is a vast subject of research, which in the course of its development embraces almost all algebra, the theory of definite integrals and the science of numbers.'

As suggested in the introduction, an account of the works of Weierstrass, Riemann, Clebsch, and later writers cannot be given in this report owing to the lack of space required for such a statement. To leave the work thus unfinished would cause the author much regret; however, there has just appeared the admirable treatise of Mr. H. F. Baker on 'Abel's Theorem and the Allied Theory,' in which the discoveries of the mathematicians just mentioned and the development of the theory of Abelian functions are treated in a very comprehensive and elegant manner.

In conclusion, the author takes much pleasure in referring to this book, at the beginning of which we are taught that no better guide can be found to the analytical developments of pure mathematics than a study of the theory of Abelian functions.

The Action of Light upon Dyed Colours.—Report of the Committee, consisting of Professor T. E. THORPE (*Chairman*), Professor J. J. HUMMEL (*Secretary*), Dr. W. N. PERKIN, Professor W. J. RUSSELL, Captain ABNEY, Professor W. STROUD, *and* Professor R. MELDOLA. (*Drawn up by the Secretary.*)

DURING the past year (1896–97) the work of this Committee has been continued as usual, and a large number of wool and silk patterns, dyed with various natural and artificial *brown* and *black* colouring matters, have been examined with respect to their power of resisting the fading action of light.

The Committee regret to state, however, that at this meeting of the Association they are unable to give an account of the results obtained, since at the earlier date this year at which Reports of Committees had to be sent to the Organising Committees the dyed patterns were still under exposure to light, so that the Report could not be prepared. It will be presented, however, at the next meeting of the Association. The Committee ask for reappointment, and for a grant of 8*l.* to carry on the work.

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Professor W. R. DUNSTAN, Mr. GEORGE GLADSTONE, Sir JOHN LUBBOCK, Sir PHILIP MAGNUS, Sir H. E. ROSCOE, *and* Professor S. P. THOMPSON.

YOUR Committee have much pleasure in being able to report that during the past year the teaching of science subjects in Elementary Schools has made considerable progress. They think it unnecessary to repeat the table showing the dearth of any such instruction, other than that of Geography before the year 1890, but give the figures for the principal class subjects for the succeeding years, showing that while 'English' (*i.e.* grammar, not literature) is gradually losing favour, the scientific subjects are all receiving more attention. It will be seen that there is a very rapid advance in regard to Elementary Science, although 'Object Lessons,' as such, appear in the return this year for the first time, and have at once taken a good place in the schools. The figures up to 1895–96, which is the latest return issued by the Education Department, are as follows :—

Class Subjects—Departments	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96
English	19,825	18,175	17,394	17,032	16,280	15,327
Geography	12,806	13,485	14,256	15,250	15,702	16,171
Elementary Science . . .	173	788	1,073	1,215	1,712	2,237
Object Lessons	—	—	—	—	—	1,079

The number of departments in 'schools for older scholars' for the year 1895–96 was 22,943, which, deducting 21 that did not take any class subject, leaves 22,922. But History was taken in 4,143, and Needlework (for girls) in 7,219 departments, and sundry minor subjects in 849, making, with the other four subjects of the table, 47,025 in all. This shows an average of more than two class subjects to each department, while in the previous year it was rather less than two. While recognising with satisfaction the increase in the returns for Elementary Science and Object Lessons, it must not be assumed that they are given throughout the schools, the latter subject being more particularly intended for the three lower standards. The next return should show a great increase in these Object Lessons, as they became obligatory on September 1, 1896, in these standards.

Specific Subjects.—Children	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96
Algebra	31,349	28,542	31,487	33,612	38,237	41,846
Euclid	870	927	1,279	1,399	1,468	1,584
Mensuration . . .	1,489	2,802	3,762	4,018	5,614	6,859
Mechanics	15,559	18,000	20,023	21,532	23,806	24,956
Animal Physiology . .	15,050	13,622	14,060	15,271	17,003	18,284
Botany	2,115	1,845	1,968	2,052	2,483	2,996
Principles of Agriculture.	1,231	1,085	909	1,231	1,196	1,059
Chemistry	1,847	1,935	2,387	3,043	3,850	4,822
Sound, Light, and Heat .	1,085	1,163	1,168	1,175	914	937
Magnetism and Electricity	2,554	2,338	2,181	3,040	3,198	3,168
Domestic Economy . .	27,475	26,447	29,210	32,922	36,239	39,794
Total . . .	100,624	98,706	108,434	119,295	134,008	146,305

The increased teaching of scientific specific subjects in the higher standards is the natural consequence of the greater attention paid to natural science in the lower part of the schools. The number of scholars examined in the above subjects is shown in the table at the bottom of previous page. This shows a fair increase in the total; the greatest proportional increase will be found to be in Mensuration, Botany, and Chemistry. In the case of the Principles of Agriculture, and in Magnetism and Electricity, there is an absolute falling off.

Estimating the number of scholars in Standards V., VI., and VII. at 605,000, the percentage of the number examined in these specific subjects as compared with the number of children qualified to take them is 24·2; but it should be remembered that many of the children take more than one subject for examination. The following table gives the percentage for each year since 1882, and shows that science is gradually recovering from the great depression of about eight years ago:—

In 1882–83	29·0 per cent.
„ 1883–84	26·0 „
„ 1884–85	22·6 „
„ 1885–86	19·9 „
„ 1886–87	18·1 „
„ 1887–88	16·9 „
„ 1888–89	17·0 „
„ 1889–90	18·4 „
„ 1890–91	20·2 „
„ 1891–92	19·7 „
„ 1892–93	20·2 „
„ 1893–94	20·9 „
„ 1894–95	22·7 „
„ 1895–96	24·2 „

The Returns of the Education Department given above refer to the whole of England and Wales, and are for the school years ending with August 31. The statistics of the London School Board are brought up to the year ending with Lady Day, 1897. They also illustrate the great advance that has been made in the teaching of Elementary Science as a class subject, and they give the number of children as well as the number of departments.

Years	Departments	Children
1890–91	11	2,293
1891–92	113	26,674
1892–93	156	40,208
1893–94	183	49,367
1894–95	208	52,982
1895–96	246	62,494
1896–97	364	86,638

The very rapid increase of the past twelve months must be regarded as highly satisfactory; but there is still room for improvement, as considerably more than half the departments for older scholars are still without this teaching.

The work under the Evening Continuation Schools Code continues to progress, as will be seen from the following table :—

Science Subjects	Units for Payment					
	England and Wales			London School Board		
	1893–94	1894–95	1895–96	1893–94	1894–95	1895–96
Euclid	595	1,086	1,648	10	29	7
Algebra	3,940	6,657	10,374	316	302	535
Mensuration	14,521	32,931	41,772	279	374	452
Elementary Physiography	2,554	4,045	6,590	37	9	5
Elementary Physics and Chemistry	6,500	7,850	6,749	79	200	152
Science of Common Things	6,223	10,350	12,906	231	262	468
Chemistry	3,484	7,814	8,222	212	455	404
Mechanics	841	1,148	1,458	230	197	209
Sound, Light, and Heat	500	1,046	861	—	15	11
Magnetism and Electricity	2,359	4,451	5,073	662	776	783
Human Physiology	5,695	8,395	7,825	91	68	56
Botany	336	547	905	5	91	97
Agriculture	3,579	4,991	4,694	—	—	—
Horticulture	438	1,140	1,812	—	—	—
Navigation	42	69	142	—	—	—
Totals	51,607	92,520	111,031	2,152	2,778	3,179

It is evident that the more mathematical subjects—Mensuration, Algebra, and Euclid—not only maintain their progress of the previous year, but continue to increase, though not so rapidly in the aggregate. Elementary Physiography and Horticulture show a great proportionate increase; while the remainder only show a slight increase or an actual decrease. In Manchester the School Board have a well-regulated system by which the scholars can rise from the Ordinary Day School, through either the Higher Grade Day Schools or Evening Continuation Schools, to the Board's Science and Art Evening Schools. These are six in number, five of which are furnished with a laboratory for the Study of Practical Chemistry. Nearly all the Science subjects in the Directory of the Science and Art Department are taught in one or other of these schools.

The Government Code for this year contains some important additions bearing upon the subject on hand. In the Committee's last report modifications in the syllabus for Mechanics and Domestic Economy (for girls) were desiderated, and a more general teaching of scientific method. In the present Code no alteration is made in respect of the subject 'Mechanics,' but, while the course for Domestic Economy remains as before, an entirely new syllabus has been provided under the name of Domestic Science, which is defined as the Science of Domestic Economy and Hygiene, and it is stated in a note that 'the instruction in this subject should be entirely experimental, the experiments as far as possible being carried out by the scholars themselves, and arranged with the object of solving a definite problem. Measurement and exact work should be encouraged.' The whole syllabus is given in the Appendix. The London School Board has already adopted this in five of its schools.

There is an important alteration in the mode in which the Government grant for specific subjects is to be assessed in the future. Hitherto it

has been on the result of the examination of the individual scholars, for which, of course, inspection with notice was necessary; henceforth the payment will be by time, and the scale of payment will be determined by the report of the Inspector on his visits without notice.

In Course H, in the Supplement to Schedule II., called 'Experimental Arithmetic, Physics, and Chemistry,' there are some alterations in the order of the work in the upper standards, with the addition of 'Floating bodies' and 'The heat unit, heat capacity, and latent heat.'

In the schedule of studies for pupil teachers there is a new column of Elementary Science (details of which are given in the Appendix), but it is only an optional subject. This has an advantage over the working under the Science and Art Department, as the matter for study is not so specialised, and it extends through the whole of the Pupil-teacher course. But there is no requirement that it should be carried out experimentally.

In the Elementary Science supplement to Schedule II., the subject matter of Standard III. in all the different Courses is unaltered; but it is made clear that it is to be taught by means of illustrative object lessons.

Teaching of Practical Housewifery, &c., must depend, not on empirical rules, but on the scientific principles underlying the actual work.

The Code of regulations for the Evening Continuation Schools is increased in bulk. The new subjects in Science are Domestic Science and Commercial Geography. The scheme for Elementary Physics and Chemistry is enlarged by the introduction of the measurement of heat, and heat capacity. An alternative scheme of instruction in Hygiene is provided, which is described as the scheme of the St. John's Ambulance Association. The detailed scheme for Commercial Geography includes a considerable amount of matter touching the Physical Geography and Climatology, and the raw productions of the countries studied. The scope of the syllabus for Domestic Science is much the same as that in the Day School Code, with the proviso that 'the applications to the home should be the results of the discoveries made in the course of the experiments, which should be undertaken in a spirit of inquiry or research.' The directions are exceedingly minute, detailing the practical work to be done at every stage of the study.

It is evident that if this kind of Science Teaching is to be given in the Elementary Schools a body of teachers must be raised up who are well indoctrinated in the new methods. This fact is being recognised now by many of the large School Boards, and under that for London in particular the classes in Practical Science for teachers, which have been conducted by Mr. Heller for some time past, are already bearing fruit; while the same may be expected of the classes in Domestic Science for women teachers, now under the management of Miss Edna Walter. The Departmental Committee on Training Colleges, of which the Rev. T. W. Sharpe (Her Majesty's Chief Inspector of Schools) is Chairman, may also be expected to do something to simplify and improve the teaching of Science by providing a more appropriate course of study than the specialised subjects of the Science and Art Department for the students at those institutions.

There has lately been held in London an important Conference of the International Congress on Technical Education, at which five members of your Committee read papers or joined in the discussion. Although it was not directly concerned with Elementary Education, there was much that

bore upon the importance and the methods of teaching Science in the primary and continuation schools as a preparation for technical studies properly so called. A full account of what took place at this Conference is being printed in the 'Journal of the Society of Arts.' It includes also a strong letter from Professor Fitzgerald in advocacy of the system which he saw carried out by Mr. Heller during the Professor's recent visit to London as a member of the Commission on Manual and Practical Instruction in Primary Schools in Ireland.

The question of improved methods of Science teaching in Elementary Schools has also been advanced by the action of the Joint Scholarships Board. Early in February Sir Philip Magnus, Chairman of the Board, wrote to the 'Times' inclosing a copy of a memorandum which had been prepared by a Committee of the Board, and had been forwarded to the Vice-President of the Council. The memorandum may be found *in extenso* in 'Education' of February 27. Its principal recommendation is as follows :—'In the opinion of this Board, in order to place "Science" on a sounder footing in Elementary Schools, and, above all, in order that the teaching of the subject may be of real value educationally, it is desirable that only one Science subject should be taught up to and within the Sixth Standard, and that the course should be a progressive one. It seems that this might be accomplished by adopting exclusively Course H, given in the Supplement to Schedule II. of the Day School Code.' It is hoped that the Education Department will be able before long to adopt the suggestion of the Board, whose object is to adapt the method of Science teaching in its earliest stages to more advanced work, so that there may be continuity in method from the Elementary Schools to the University.

APPENDIX.

Domestic Science.—The Science of Domestic Economy and Hygiene.

1*st stage.*—Measurements of weight and size (volume), preferably in the Metric system. Measurement of heaviness or density of water, milk, &c.

Floating bodies—the lactometer.

General effects of heat on matter in its three states, with applications to cooking, boiling, ventilation, hot-water supply, steaming, freezing, clinical and household thermometers, weight of air, moisture in air, drying and airing clothes, weather forecast, distillation, solution, and solubility, modes of heating the dwelling, transmission of heat, clothing.

2*nd stage.*—Effects of heat on food materials, such as sugar, cheese, flour, eggs, fat and lean meat. Modes of cooking : yeast, baking powder, a loaf of bread. Effects of heat on mineral matter, such as iron, copper, brimstone.

Rusting of iron, and general nature of air.

Burning of a match, candle, lamp, and phosphorus. Oxygen the active part of air. Burning of carbon, coal, or coke in air or oxygen. Fuel and combustion. Coal gas, burners, and gas stoves. The gas meter. Carbonic acid gas, its presence in the atmosphere, its origin.

3*rd stage.*—Sources and impurities of water. Water supply and filtration. Hardness of water. Water a product of combustion. Composition of water.

Acids and alkalis, soap, soda, and cleaning.

Ventilation and warming more fully considered.

The alimentary system. Foods, composition and functions. Classes of foods.

Decay and disease; disinfectants.

Elementary Science.

Candidates for probation.—Simple mechanical laws in their application to common life and industries.

Candidates for engagement as Pupil-teachers.—Outlines of physiology in its bearing on health and work.

First year.—Physiography. Matter. Forms of matter. Indestructibility of matter. Mass, volume, density, specific gravity and weight. Centre of gravity.

Force, motion, and inertia. The parallelogram of forces. Composition and resolution of forces. Conversion of rectilinear into circular motion.

The Mechanical powers.—Principles of the lever, the pulley, the inclined plane, and the screw.

Energy.—Heat, radiation, electricity, and chemical action as forms of energy. Mechanical work.

Second year.—Physiography. Heat and temperature. Discrimination between heat and temperature. Effects of heat. The measurement of temperature by thermometers. Change of state caused by heat, as in ice, water, and steam.

Radiation.—Rectilinear propagation of radiation. Reflection and refraction of radiation. The analysis of light by a prism, and its recomposition. The colour disc. The visible spectrum.

Third year.—Physiography.—Chemical composition of matter. Mixtures and compounds. Water: its composition proved by analysis and synthesis; its physical properties. Elementary properties of oxygen, nitrogen, hydrogen, carbon, iron, and mercury: and of water, carbon dioxide, lime, silica, and the alkalis, common salt, iron oxide, and mercuric oxide.

Terrestrial Magnetism.—Properties of the lodestone and artificial magnets. The earth a magnet. Primary laws of magnetic attraction and repulsion. Dip. The earth's magnetic poles.

Fourth year.—No scheme of study is provided; but at the Queen's Scholarship examination, marks will be given for success in passing one of the Science subjects under the Science and Art Department.

Isomeric Naphthalene Derivatives.—Report of the Committee, consisting of Professor W. A. TILDEN *(Chairman) and* Dr. H. E. ARMSTRONG *(Secretary).*

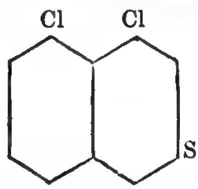
DURING the past year further important evidence has been obtained bearing on the constitution of the tri-derivatives of naphthalene confirmatory of the conclusions previously arrived at, and also affording proof that the interaction of phosphorus pentachloride and sulphonic chlorides is in all cases a trustworthy method of determining constitution by reference to

chloronaphthalenes (cf. Armstrong and Wynne, 'Proc. Chem. Soc.' 1897, 152).

It has been found that the chloronaphthalene-disulphonic chlorides afford a relatively small amount of trichloronaphthalene, and that a considerable portion of the product is an intermediate compound—the *di*-chloronaphthalene-*mono*-sulphonic chloride. From the results obtained in the case of several α-β-disulphonic acids, it appears that of the two, as was to be expected, the α-sulphonic group is the more readily displaced.

A series of remarkable observations have been made of the occurrence of isomeric change in the case of 1 : 1′-dichloronaphthalene and its derivatives.

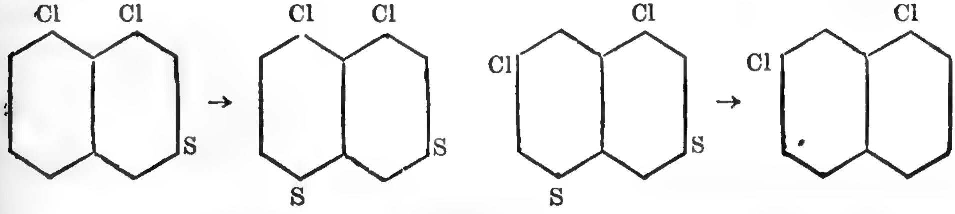
The α-sulphonic acid of 1 : 1′-dichloronaphthalene is hydrolysed at about 230°, and gives only 1 : 1′-dichloronaphthalene whatever be the hydrolytic agent used. The β-sulphonic acid represented by the formula,



however, which cannot be hydrolysed below 285°, gives one or other of no fewer than *three* isomeric dichloronaphthalenes—the 1 : 1′, 1 : 2′, or 1 : 4′ modifications—according to the agent used.

When hydrolysed at 290° by means of a solution containing 1 per cent. of sulphuric acid or one containing about 50 per cent. of phosphoric acid, it behaves normally, yielding 1 : 1′-dichloronaphthalene. But if stronger solutions of either acid be used, much of the salt is carbonised, and in this case a small amount of 1 : 4′-dichloronaphthalene is obtained as the sole volatile product. When concentrated muriatic acid is used as the hydrolytic agent, as much as 20 per cent. of the theoretical amount of the 1 : 4′-compound is formed.

Lastly, if the potassium salt be mixed with sulphuric and phosphoric acids, and superheated steam be passed through the mixture, 1 : 2′-dichloronaphthalene is the sole product of hydrolysis. In this last case it is not improbable that further sulphonation precedes hydrolysis, and that this has the effect of preventing the transference of chlorine to the para-position, so that the 1 : 2′ is formed instead of the 1 : 4′ modification; thus :



The trichloronaphthalenes derived from 1 : 4′-dichloronaphthalene are also, it appears, susceptible of 'isomeric' change.

Considerable attention has been paid during the year to the study of the derivatives of α-methoxy- and α-ethoxy-naphthalene in comparison with those of α-naphthol. It appears to be a much less 'active' compound

than the latter, for example, readily yielding a monobromo-derivative, whereas it is almost impossible to prevent the exclusive formation of dibromonaphthol from α-naphthol.

A series of sulphonic acids have been prepared from α-ethoxynaphthalene and its bromo-derivatives.

The Carbohydrates of the Cereal Straws.—Report of the Committee, consisting of Professor R. WARINGTON (*Chairman*), C. F. CROSS (*Secretary*), *and* MANNING PRENTICE. (*Drawn up by the* SECRETARY.)

THE work upon the barley crop of 1896, which was reported in outline to the Chemical Section in a paper read by Mr. Cross, has been more fully dealt with in a paper read subsequently, and published in the 'Journal of the Chemical Society,' 1896, pp. 804–818. The subject was also dealt with from the more special point of view of the relation of the furfuroid constituents of these straws to the important problems of animal digestion and alcoholic fermentation in a paper published in the 'Journal of the Fed. Inst. of Brewing,' 1897, Pt. 1.

The investigations have been continued without interruption. We have further and more closely studied the products of acid hydrolysis of the cereal straws and of the celluloses isolated from them, and the main results of these researches are embodied in a paper read at the Meeting of the Chemical Society, London, on June 17.

Generally the results of the preceding paper (*loc. cit.*) are amplified and confirmed. As it had been previously shown that the furfural-yielding constituents of fodder plants are in large measure hydrolysed and assimilated by the animal organism, so the evidence is accumulating that certain of these compounds when fully hydrolysed (to monoses) by artificial processes are susceptible of alcoholic fermentation.

It having been finally established that the pentoses themselves are entirely resistant to the attack of the yeast cell, it follows that we are dealing with a class of furfural-yielding carbohydrates, *not* pentoses.

At the same time the reactions of these compounds clearly indicates that they are pentose-derivatives, and most probably methylene ethers of the C_5 sugars of the general formula $C_5H_8O_3 \langle {}^{O}_{O} \rangle CH_2$.

It is difficult to devise reactions of decomposition or synthesis by which such a constitutional formula could be finally verified. The literature of the analogous compound diperonal $HOC.C_6H_3 \langle {}^{O}_{O} \rangle CH_2$, but with an aromatic in place of a pentose residue, may be cited in evidence of the exceptional difficulty of the problem presented.

The authors are glad to report that through the kindness of friends they have now access to a vessel enabling them to operate upon a large weight (7 kilos.) of the raw materials.

Working upon this extended scale, and upon the basis of the results established by long investigation and previously reported to the Association, we may confidently expect more positive and, we hope, final results.

The Electrolytic Methods of Quantitative Analysis.— Fourth Report of the Committee, consisting of Professor J. EMERSON REYNOLDS (*Chairman*), Dr. C. A. KOHN (*Secretary*), Professor P. FRANKLAND, Professor F. CLOWES, Dr. HUGH MARSHALL, Mr. A. E. FLETCHER, *and* Professor W. CARLETON WILLIAMS.

SINCE the last report, which included an examination of the electrolytic methods for the determination of bismuth, antimony, and tin, and for the separation of the two latter, the experimental work of the Committee has been continued. The investigations on the determination of cobalt, nickel, and zinc are practically finished; also further work on the determination of bismuth and its separation from other metals; but the Committee prefer to delay the publication of these results until the next report in order to make them as complete as possible.

The Committee ask for reappointment, with a grant of 10*l*.

The Production of Haloids from Pure Materials.—Report of the Committee, consisting of Professor H. E. ARMSTRONG, Professor W. R. DUNSTAN, Mr. C. H. BOTHAMLEY, Mr. J. T. CUNDALL, *and* Mr. W. A. SHENSTONE (*Secretary*), *appointed to investigate the Production of Haloids from Highly-purified Materials.*

THE investigation undertaken by this Committee, as has been previously reported, has been greatly delayed by the difficulty experienced in their attempts to obtain a supply of chlorine satisfactory, both as regards origin and quality, for the work to be done.

During the past year, however, the Secretary has succeeded in preparing (by the electrolysis of silver chloride) a suitable supply of the element in question.

A full account of the method of obtaining chlorine from this source, and of the experiments that have been made with it, has already been published in the 'Journal of the Chemical Society of London.'[1] It is therefore only necessary to state that novel and stringent means were taken to secure the dryness of all the materials employed in the various experiments, and that advantage has been taken of the opportunity which has arisen to examine once more the behaviour of chlorine in sunlight, and also its behaviour under the influence of the silent discharge of electricity.

The following is a summary of the chief results obtained:—

1. The introduction of a new source of highly-purified chlorine.

2. The observation that highly-purified chlorine, after it had been dried by new and very stringent methods, still interacted rapidly and completely with specimens of highly-purified and carefully dried mercury made by several different methods.

3. That highly-purified and carefully dried bromine reacts readily and completely with purified mercury.

[1] 'Observations on the Properties of some Highly-purified Substances,' *Trans. Chem. Soc.*, 1897, by W. A. Shenstone.

4. That iodine purified by the 'Stas Method,' and carefully dried, reacts readily and completely with purified mercury.

It may be pointed out that these particular elements were selected for examination because they are among those whose interactions have not hitherto been found to be influenced by the presence or absence of traces of water-vapour among the acting substances; and because it was thought that we are now at a stage at which it is more important to re-examine actions belonging to this class, than to seek for fresh instances of substances which cease to interact when highly dried.

5. That highly-purified chlorine does not, like oxygen, undergo condensation when submitted to silent discharge of electricity.

6. That highly-purified chlorine is very little affected by exposure to direct sunlight, but that it becomes more sensitive if rendered impure by the adding of traces of moist air.

7. It has been noticed incidentally that lead glass may be heated to its softening point in well-dried chlorine, without showing any signs that it has been attacked, although in the damp state this kind of glass is readily attacked by chlorine.

8. A new form of vacuum trap is described in the paper referred to.

It is recommended that the Committee be not reappointed, as no further pecuniary assistance is likely to be needed, and the work can now be carried on by those who are engaged upon it without further corporate action.

Life Zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Mr. J. E. MARR (*Chairman*), Mr. E. J. GARWOOD (*Secretary*), *and* Mr. F. A. BATHER, Mr. G. C. CRICK, Mr. A. H. FOORD, Mr. H. FOX, Dr. WHEELTON HIND, Dr. G. J. HINDE, Mr. P. F. KENDALL, Mr. J. W. KIRKLEY, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, Mr. G. H. MORTON, Professor H. A. NICHOLSON, Mr. B. N. PEACH, Mr. A. STRAHAN, Dr. H. WOODWARD, *and* Dr. TRAQUAIR, *appointed to study the Life Zones in the British Carboniferous Rocks.* (*Drawn up by* Mr. GARWOOD.)

IN consequence of the early date on which it is necessary to submit reports, little work has been done this year up to the present time, but it is hoped that during the summer months progress may be made with the work of the Committee, and collections may be obtained from localities of special importance.

At present a collector is engaged upon the fauna of the Millstone Grit at Eccup, five miles north of Leeds, where a fossiliferous black shell has been met with during the excavation of a puddle-trench for a reservoir. The bed occurs about the centre of the 'Middle Grits' of the Yorkshire Millstone Grits.

The bed, which was discovered by Mr. Percy Kendall, some three years ago, contains a rich Marine fauna, which has not yet, however, been properly worked out. The fauna includes species of Nucula and Leda in great abundance and in excellent preservation, also numerous individual specimens of Lingula and Discina. Gasteropods occur, and a few specimens of Goniatites, together with well-preserved specimens of Conularia.

Several specimens of Dithyrocaris have been found, and a single specimen of a minute Trilobite, cf. *Brachymetopus Ouralicus.* Fish remains referable to two genera have been identified.

The fauna appears to bear little resemblance to that of the Cayton Gill beds of Nidderdale, which lie at approximately the same horizon in the Millstone Grit.

On the whole, the fauna appears to resemble in many points that of the Ridsdale Ironstone shell of the Bernician beds of South Northumberland.

The Committee hope that the information obtained from this deposit will be of value, in consideration of the comparative neglect with which the fauna of the Millstone Grit has hitherto been treated.

Owing to the temporary nature of the exposure the Committee considered it advisable to expend a considerable portion of the grant in obtaining the services of a competent collector, who has spent a fortnight in making as exhaustive a collection as possible from the locality, under the superintendence of Mr. Percy Kendall. The accounts have not yet however, come in, and the Committee cannot therefore at present draw upon the grant generously placed at their disposal by the Association, but ask that the sum granted may be carried over to next year. They also ask that a similar sum may be granted for that year.

The Secretary has been in correspondence with the various members of the Committee as to the best methods of forwarding the objects of the Committee. From many of these he has received valuable suggestions, and it is hoped that reports will be furnished at an early date from each of the members for special districts, giving detailed sections of the rocks in their individual areas, and stating what reliable information has already been collected regarding their fossil contents, and what yet remains to be done in this connection.

Structure of a Coral Reef.—Report of the Committee, consisting of Professor T. G. BONNEY (*Chairman*), Professor W. J. SOLLAS (*Secretary*), Sir ARCHIBALD GEIKIE, Professors J. W. JUDD, C. LAPWORTH, A. C. HADDON, BOYD DAWKINS, G. H. DARWIN, S. J. HICKSON, *and* A. STEWART, Admiral W. J. L. WHARTON, Drs. H. HICKS, J. MURRAY, W. T. BLANFORD, C. LE NEVE FOSTER, *and* H. B. GUPPY, Messrs. F. DARWIN, H. O. FORBES, G. C. BOURNE, A. R. BINNIE, J. W. GREGORY, W. W. WATTS, *and* J. C. HAWKSHAW, *and* Hon. P. FAWCETT, *appointed to consider a project for investigating a Coral Reef by Boring and Sounding.*

As the expenses of the expedition were covered by the grants from funds administered by the Royal Society, the sum of 40*l*., granted by the Association at Liverpool, has not been drawn. But another expedition has been already sent out from Sydney under the auspices of Professors Anderson Stuart and Edgeworth David and others, with machinery to overcome the difficulties which were fatal to the first attempt, and the Committee ask that they may be reappointed, and that the grant made last year, and not drawn, be renewed as a contribution to the expenses of the new undertaking.

Photographs of Geological interest in the United Kingdom.—Eighth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Mr. J. E. BEDFORD, Mr. E. J. GARWOOD, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. A. S. REID, Mr. J. J. H. TEALL, Mr. R. H. TIDDEMAN, Mr. H. B. WOODWARD Mr. F. WOOLNOUGH, *and* Professor W. W. WATTS (*Secretary*). (*Drawn up by the Secretary.*)

THE Committee have the honour to report that during the past year 364 new photographs have been received, bringing the total number in the collection up to 1,751. The early date of this year's meeting has made it necessary to close the lists earlier than usual, but in spite of this the number of new photographs considerably exceeds the number received in any previous year, although there have only been nine months to collect in, and the harvest of some of the best months will not be reaped till next year.

Adding to this large number 219 prints and 81 slides given to the loan collection, the increment is more than double that of any former year. As well as this, 27 prints have been sent to renew old ones, lost, faded, or withdrawn. The total number thus reaches 691. Fifty-three photographs and several duplicates have been received since this Report was sent in, and will be acknowledged next year.

From the detailed list it will be seen that eight new counties are now partially represented, and progress has been made in eleven others, hitherto poorly represented. Amongst the more notable donations may be mentioned a large series of views in Wealden strata by Dr. Abbott, some very beautiful Nottingham photographs by Messrs. Burton, of Leicester, a very instructive series from North Staffordshire by Mr. Armstrong, a set from the Sgurr of Eigg by Dr. R. D. Roberts, a series of Yorkshire caves by Mr. Cuttriss, sets from County Dublin, Yorkshire, and the Isle of Man by Mr. Reynolds, and several interesting pictures from North Devon and the Isle of Wight by Mr. F. Mason Good. Professor Allen contributes a good series of Charnwood and Nottingham views, Mr. Bingley sets from the Yorkshire Dales and North Wales, Mr. St. J. Phillips a most useful group from North Ireland, and Mr. Whitaker several valuable prints. Last, but not least, the Committee wish to give especial mention to the munificent gift by Mr. R. Welch, of Belfast, of 100 new platinotypes, which are not only perfect in the technical skill and the process employed, but artistic and pictorial as well, while, from a strictly geological point of view, they are so good that not one could be spared from the collection. In addition to this he has given 50 prints in previous years, and 25 duplicate prints and 7 slides this year.

For other valuable new additions to the collection, the Committee have the pleasure of expressing their gratitude to those donors, too numerous to mention here, whose names are given in list 1.

The usual summary follows. It is carefully corrected by reference to the actual contents of the collection so as to show its exact state, and it will be useful in indicating the places in which it is advisable to start new work. A glance will show that there are many areas of great geological interest in England, as well as in Scotland and Ireland, of which we have

at present no photographic survey. The Committee desire especially to draw attention to the following districts :—Areas of large and typical physical features, such as the Pennine and Pendle Ranges, the South Wales coalfield and its borders, the district of the Arans, Arenigs, and Cader Idris, the Harlech Mountains, the Yorkshire Dales, the Cotteswolds and South Downs, the Malverns, and the Silurian ground of the Welsh border; the Yorkshire Moors, Lincolnshire, the area of the Northampton Oolites, the Oxford district, Seaton and Blackdown, Central Wales, and Anglesey :

In Scotland, the North-west and Central Highlands, the Outer Hebrides, Mull, the Sidlaws and Ochil Hills, and the Southern Uplands :

In Ireland, the Carlingford and Slieve Gallion areas, Kerry Cork, the Limerick Basin, Waterford, and Wicklow.

—	Previous collection	New additions (1897)	Total	Duplicates		
				Prints	Slides	Total
ENGLAND—						
Bedford	—	—	—	—	—	—
Berks	3	—	3	—	—	—
Buckingham	—	—	—	—	—	—
Cambridge	—	—	—	—	—	—
Cheshire	44	4	48	8	3	11
Cornwall	36	—	36	1	2	3
Cumberland	4	2	6	—	—	—
Derby	25	2	27	1	—	1
Devon	72	17	89	2	4	6
Dorset	39	12	51	3	3	6
Durham	23	—	23	1	—	1
Essex	1	—	1	—	—	—
Gloucester	2	4	6	1	—	1
Hants	6	13	19	1	—	1
Hereford	—	—	—	—	—	—
Hertford	7	—	7	—	—	—
Huntingdon	—	—	—	—	—	—
Kent	39	19	58	9	—	9
Lancashire	39	2	41	5	5	10
Leicester	84	7	91	10	9	19
Lincoln	—	1	1	—	—	—
Middlesex	3	—	3	—	—	—
Monmouth	1	3	4	1	—	1
Norfolk	3	7	10	5	—	5
Northampton	—	—	—	—	—	—
Northumberland	24	3	27	—	—	—
Nottingham	2	10	12	1	—	1
Oxford	1	—	1	—	—	—
Rutland	—	—	—	—	—	—
Shropshire	25	1	26	5	3	8
Somerset	29	10	39	5	3	8
Stafford	12	14	26	5	1	6
Suffolk	1	1	2	—	—	—
Surrey	8	9	17	2	1	3
Sussex	—	8	8	—	—	—
Warwick	7	4	11	1	—	1
Westmoreland	9	1	10	—	—	—
Wiltshire	1	—	1	—	—	—
Worcester	2	—	2	1	—	1
Yorkshire	288	33	321	41	17	57
Total	840	187	1027	109	51	159

—	Previous collection	New additions (1897)	Total	Duplicates		
				Prints	Slides	Total
Wales—						
Anglesey	—	—	—	—	—	—
Brecknock	—	—	—	—	—	—
Cardigan	—	—	—	—	—	—
Carmarthen	—	—	—	—	—	—
Carnarvon	52	10	62	13	10	23
Denbigh	13	—	13	1	—	1
Flint	5	—	5	—	—	—
Glamorgan	9	3	12	2	—	2
Merioneth	14	5	19	2	—	2
Montgomery	8	1	9	6	—	6
Pembroke	—	1	1	—	—	—
Radnor	—	1	1	—	—	—
Total	101	21	122	24	10	34
Channel Islands	11	3	14	—	—	—
Isle of Man	21	9	30	2	1	3
Scotland—						
Aberdeen	2	—	2	—	—	—
Arran	1	—	1	—	—	—
Argyll	18	8	26	1	—	1
Ayr	1	—	1	1	—	1
Banff	—	1	1	—	—	—
Berwick	—	—	—	—	—	—
Caithness	4	—	4	2	—	2
Cromarty	—	—	—	—	—	—
Dumbarton	—	—	—	—	—	—
Dumfries	—	—	—	—	—	—
Edinburgh	40	—	40	10	—	10
Elgin	8	1	9	7	2	9
Fife	7	—	7	6	1	7
Forfar	7	—	7	—	—	—
Haddington	4	—	4	1	—	1
Inverness	20	4	24	—	—	—
Kirkcudbright	3	—	3	—	—	—
Kincardine	—	—	—	—	—	—
Lanark	4	—	4	3	2	5
Linlithgow	—	—	—	—	—	—
Nairn	—	—	—	—	—	—
Orkney	1	—	1	—	—	—
Peebles	—	—	—	—	—	—
Perth	14	1	15	3	—	3
Renfrew	1	—	1	—	—	—
Ross	—	—	—	—	—	—
Roxburgh	—	—	—	—	—	—
Selkirk	—	—	—	—	—	—
Shetland	—	—	—	—	—	—
Stirling	13	—	13	2	—	2
Sutherland	3	—	3	2	—	2
Wigtown	—	—	—	—	—	—
Total	151	15	166	38	5	43
Ireland—						
Antrim	130	34	164	18	7	25
Armagh	2	—	2	—	—	—

—	Previous collection	New additions (1897)	Total	Duplicates		
				Prints	Slides	Total
IRELAND (*continued*)—						
Cavan	—	1	1	—	—	—
Clare	5	3	8	—	—	—
Cork	1	—	1	—	—	—
Donegal	14	21	35	2	—	2
Down	41	14	55	11	4	15
Dublin	12	9	21	2	1	3
Fermanagh	2	1	3	1	—	1
Galway	1	22	23	3	—	3
Kerry	—	—	—	—	—	—
Kildare	—	—	—	—	—	—
Kilkenny	—	—	—	—	—	—
King's Co.	—	—	—	—	—	—
Leitrim	—	—	—	—	—	—
Limerick	1	—	1	—	—	—
Londonderry	13	6	19	1	—	1
Longford	—	—	—	—	—	—
Louth	1	—	1	—	—	—
Mayo	—	6	6	1	—	1
Meath	—	—	—	—	—	—
Monaghan	—	—	—	—	—	—
Queen's Co.	—	—	—	—	—	—
Roscommon	—	—	—	—	—	—
Sligo	—	2	2	—	—	—
Tipperary	—	—	—	—	—	—
Tyrone	—	—	—	—	—	—
Waterford	—	—	—	—	—	—
Westmeath	—	—	—	—	—	—
Wexford	—	—	—	—	—	—
Wicklow	—	—	—	—	—	—
Total	223	119	342	39	12	51
ROCK-STRUCTURES, &c.	40	10	50	6	2	8
ENGLAND	840	187	1027	109	51	160
WALES	101	21	122	24	10	34
CHANNEL ISLANDS	11	3	14	—	—	—
ISLE OF MAN	21	9	30	2	1	3
SCOTLAND	151	15	166	38	5	43
IRELAND	223	119	342	39	12	51
ROCK STRUCTURES	40	10	50	6	2	8
Total	1387	364	1751	218	81	299

A special effort has been made this year to reach persons and districts not hitherto reached, and a large number of circulars has been despatched to geologists and photographers and to Societies established by both these classes of persons. It is difficult to get those who are not geologists to take any interest in the subject, and almost impossible to persuade them to photograph objects solely for their geological value. Many of the photographs taken by those who are not geologists are, however, so important that it would be well if they would submit their albums to the Committee, so that the latter might select such prints as are of permanent geological interest. The collection now contains photographs of what

may be called the more sensational geological phenomena. What is now rather more required is the steady surveying of ordinary, and especially temporary, features and phenomena. Picked points on retreating and advancing shore lines should be photographed at regular intervals; sections in variable deposits should be taken as the excavation of them proceeds, and out-of-the-way districts should also be registered, even if they only yield ordinary phenomena. Important as it is that fossils should be accurately and faithfully figured, it is equally essential that phenomena in the field should be figured in a way that is not only accurate, but includes, without accentuation, the interpretation of the investigator, while it registers facts which may have escaped his observation.

In order to glean copies of the original photographs used as the bases for illustrations in papers and books, a circular has been furnished to Editors of Geological publications, and by the kindness of the Societies and their Editors these have been sent out to the contributors of papers so illustrated. The plates and other illustrations published are, when possible, mounted by the side of the original photographs, and yearly lists are published in the Report (list 5). The Committee are indebted to the Editors of the publications of the Geological Societies and Associations of London, Liverpool, Edinburgh, Glasgow, Cornwall, Yorkshire, Dublin, and Belfast, and to the Editor of the 'Geological Magazine' for help in this connection.

Friendly notices of the work of the Committee have been published in 'Nature,' 'Science Gossip,' several photographic journals, the 'Standard,' the 'Irish Naturalist,' the 'Transactions of the Woolhope Club,' and elsewhere; while an illustrated paper on the subject was published in the 'Practical Photographer' for April 1897; and another, illustrated by reproductions of photographs kindly lent for the purpose by Miss Andrews, Mr. Bingley, and Mr. Garwood, was published by the Secretary in the first three numbers of the 'Geological Magazine' for 1897. A short paper on the subject was also read by the Secretary to the South-Eastern Union of Natural History Societies in 1896. Prizes have been offered by the publishers of the 'Practical Photographer' for specimen local surveys, including the geological phenomena of a particular district. Albums containing recent additions to the Collection have been exhibited at the Royal Institution, the Geological Society, and the Geologists' Association.

The results of these efforts have been gratifying in several directions. Photographic surveys have been started in Bolton and Devon; each of these includes geological work. The following Clubs and Societies have definitely undertaken to photograph in their own districts —The North Staffordshire Naturalists' Field Club, the University of Durham Philosophical Society, the Woolhope Field Club, the Dublin Field Club, and the Burton Natural History Society. From these sources valuable results have already accrued, and further work may be confidently looked forward to next year.

Much labour has been expended in getting the collection into thorough order, and it is hoped that the greater part of this work is now satisfactorily accomplished. All mounted photographs, to the number of about 1,700, are accessible for reference in the Library of the Museum of Practical Geology at 28 Jermyn Street, S.W., where they can be inspected on application to the Librarian. They are classified geographically and grouped according to countries and counties in twenty-three albums, so arranged that their contents can be expanded as new photographs are

received. In addition to the mounting of most of the photographs received during the last three years it has been necessary to unmount and remount on standard, interchangeable, guarded mounts over 500 of the older photographs. Considering the risk involved in this work, but little real damage has been done to the prints, and the majority have come through the ordeal unscathed, while not one has been irretrievably damaged. Many of the descriptive forms have been rewritten and expanded, and a large number which had been lost or never sent in have been written up. The localities of all but two of the photographs in the collection have been accurately ascertained, though there was in some cases no written clue to them. Many photographs have been critically examined, and additional points of interest in them have been discovered and explained on the mounts or forms. The Committee express their thanks to Mr. Strahan, Mr. Lamplugh, Mr. Gibson, Mr. Leighton, Mr. Nichols, Mr. Watson, Mr. Welch, Mr. Whitaker, Mr. Shipman, Mr. De Rance, Mr. Woodward, Mr. Goodchild, Mr. Brook, Mr. Hunt, and several others for services in this direction. References to published descriptions and plates are being filled up wherever possible. In many cases it has been discovered that the photographs are beginning to possess a special interest from the change or disappearance of the objects photographed. Thus the pump at Marino, Co. Down, has been washed away, and there are photographs of Shakespeare Cliff before the landslip, to compare with those taken since, and a print of Eccles Tower, free from sand dunes, before it fell. On the other hand, the Carboniferous Forest shown in Photographs 33, 34, 35, and 939 has now been carefully protected by a building. The beautiful section (972) showing a chalk cliff and screes buried under Tertiary Basalt has been quarried away.

Concurrently with the rearrangement a card catalogue of the whole collection has been made, and this is so arranged as to minimise the future labour of registering new photographs, while at the same time it secures a ready means of recording localities and particulars with accuracy. The cards are used for acknowledgment to donors, who can thus correct the particulars to be finally entered in the published lists. A county list and an abbreviated numerical list have also been written, and for the first time it has been possible to check the whole contents of the collection. This has shown that, in spite of the difficulties of keeping a large set of unmounted and miscellaneously mounted prints, only 3 per cent. of those registered in the published list were not to be found, a result which reflects much credit on the care exercised by the former Secretary, Mr. Jeffs. Quite 1, and perhaps 2, per cent. of this apparent loss is due to clerical errors in entering contributions in the published lists before they had been actually received; the other 1 per cent. seems to represent actual loss, but this is to some extent compensated by the finding of photographs which had not been registered in the printed lists. The good nature of the majority of the donors of the best photographs has enabled the Committee to make good almost all photographs of real geological value, and at the present time not more than sixteen of the photographs registered in the published lists are absent from the collection. The numbers of the prints which cannot be found or replaced have been applied to new photographs received within the year, and thus the numbering represents with fair accuracy the actual state of the whole collection; numbers below 1,400 in the list (No. 1) are those which have been thus transferred, and any photographs which may be attached to

such numbers in previous lists must now be finally cancelled, as the Secretary has failed to recover them, or else they have never actually been in the collection. With some of these numbers it will be noticed that no photograph has ever been associated.

The Committee desire to express their warmest thanks to those donors who have so kindly enabled them to bring the collection into a perfect state up to date. The following names should be mentioned with thanks: Mr. Stewart, Mr. Defieux, Mr. Bingley, Miss Andrews, Dr. Stolterfoth, Mr. Brook, and Mr. Welch.

List No. 2 comprises lost photographs which have been renewed, and List No. 3 is necessitated by the slight confusion which has occurred in connection with the supply of missing photographs and the filling of gaps. Here, again, many of the original donors have given help; their names are mentioned with thanks in this list.

Certain Scientific Societies have been in the habit of issuing specially taken photographs to their members, and several of them have sent sets to the Committee in past time. An effort has been made to make these sets more perfect, and the Societies in question have given ready help. The Yorkshire Geological and Polytechnic Society and the Liverpool Geological Society, for example, have overhauled the list and promised to contribute such of their prints as are still to be got to complete our set.

The Secretary will be very pleased to receive help from geologists in annexing fuller and more accurate descriptions of the geological features to the photographs, in order that they may become of the utmost use as a work of reference. He will also welcome corrections and additional information from those who inspect the collection. Several persons anxious to obtain examples to illustrate both geological and geographical phenomena have visited the collection, and to more than one it has been found of much use for the purpose; as it becomes larger and more representative it must become increasingly important and useful in this respect. The Committee will welcome suggestions as to the best method by which eventually it may be possible to enable those interested in such things to obtain reproductions or prints without imposing a strain on the time and good-nature of willing contributors.

It has long been evident that, while it is essential that the main collection should be permanently lodged at a central place where it can be used for reference, it would be a great advantage if some portion of it could be allowed to circulate amongst geological and photographic Societies, in order that the kind of work necessary and its utility might be made obvious to those bodies and persons likely to take it in hand. For this purpose the best thing appeared to be the formation of a duplicate loan collection selected from the best and most typical photographs in the main collection and arranged geologically. A few duplicates found in the collection have been set aside for this purpose, and an appeal has been made to contributors to give prints or slides of those photographs most suitable for the purpose. To this appeal there has been a most liberal response, and a loan collection has been inaugurated. It now numbers 219 prints and 81 slides, of which a separate classified list is annexed (No. 4). A description will be written to serve as an account of the slides or as labels for the prints, and the two parts of the loan collection will be ready for circulation amongst such Societies and Clubs as are prepared to pay the expenses of packing and carriage, and to make good any

damage. The Secretary will be glad to receive early application from Societies wishing to avail themselves of the offer of this loan, that arrangements may be made in good time.

The photographs in this selected series are naturally of the kind which would be most useful to those who wish to obtain typical examples for teaching purposes or for exhibition in illustration of papers; and therefore, whenever it has been possible to arrange it, an address is given whence prints or slides may be purchased. But it must be distinctly understood that the Committee can undertake no responsibility or correspondence in this matter. All information possible will be circulated with the collection, and there the Committee's work must end; would-be purchasers must make their own arrangements with photographers, in whom exclusively the copyright remains vested.

The Committee, in forming this collection, are much indebted to the donors whose names are mentioned at the end of List 4, and particularly to Mr. Bingley (who has given 39 prints and 23 slides) Mr. Welch (25 and 7), Mr. Goodchild (17), Mr. Nichols, Mr. Watson, Mr. Defieux, Mr. Armstrong, Miss M. K. Andrews, and Captain McDakin.

The Secretary will be grateful if the donors of photographs will kindly look through the parts of the lists in which they are interested and notify to him any slips in the spelling of proper names, in the geographical or geological descriptions, or mistakes of any other kind which occur in the Report.

The Committee recognise that their work is yet far from completion, and they therefore ask for their reappointment with a small grant to defray some of the expenses connected with the mounting, storing, and collection of photographs.

EIGHTH LIST OF GEOLOGICAL PHOTOGRAPHS

(TO JUNE 1897).

NOTE.—This list contains the subjects of geological photographs copies of which have been received by the Secretary of the Committee since the publication of the last Report. Photographers are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference. Their own numbers, where given, are added, in the same order, to enable them to do so.

Copies of photographs desired can, in most instances, be obtained from the photographer direct, or from the officers of the Local Society under whose auspices the views were taken.

The price at which copies may be obtained depends on the size of the print and on local circumstances, over which the Committee have no control.

The Committee find it necessary to reiterate the fact that they *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should *not* be addressed to the Committee, but to the photographers direct.

The very best photographs lose half their utility, and all their value as documentary evidence, unless accurately described; and the Secretary would be grateful if, wherever possible, such explanatory details as can

be given were written on the forms supplied for the purpose, and *not on the back of the photograph or elsewhere.* Much labour and error of transcription would thereby be saved. A local number by which the print can be recognised should be written on the back of the photograph and on the top right-hand corner of the form.

Copies of photographs should be sent *unmounted* to W. W. Watts, Mason College, Birmingham, and forms may be obtained from him.

The size of photographs is indicated as follows :—

L = Lantern size.	1/1 = Whole plate.
1/4 = Quarter-plate.	10/8 = 10 inches by 8.
1/2 = Half-plate.	12/10 = 12 inches by 10, &c.

E signifies Enlargements.

* indicates that photographs and slides may be purchased from the donors.

LIST 1.

ENGLAND.

CHESHIRE.—*Photographed by* C. A. DEFIEUX, 50 *Windsor Road, Tue Brook, Liverpool.* 1/2.

Regd. No.		
1560	(8) Hilbre Island. . . .	Fault in Keuper Sandstone. 1891.
1561	Hilbre Island, W. . .	Fissure in Triassic Sandstone. 1890.
1562	„ „ . . .	Trias Sandstone. 1890.
1563	Hilbre Island. . . .	False bedding in Trias Sandstone. 1890.

CUMBERLAND.—*Photographed by* J. B. BAILEY, 27 *North Street, Maryport.* 1/2.

811	Maryport, looking north. . .	Peat, Raised Beach, and Glacial Drift. 1896.
812	„ „ south. . .	„ „

DERBYSHIRE.—*Photographed by* Mr. FRITH. *Presented by* W. WHITAKER, *F.R.S.* 1/1.

1557	R. Wye, Cressbrook. . . .	Carboniferous Limestone.

Presented by W. WHITAKER, *F.R.S.* 10/8.

1558	Blackwell Dale.	Carboniferous Limestone.

DEVONSHIRE.—*Photographed by* A. K. COOMARA-SWAMY, *Worplesdon, Guildford.* 1/1. (*E*)

1445	(Dev. 1) Hotel Cliff, Ilfracombe.	Synclinal fold in Devonian Rocks. 1896.
1446	(Dev. 2) Wild Peas Beach, Combe Martin.	Folding of Hangman Grit. 1896.

1/4.

1553	(Dev. 3) Croyde Bay. . .	Upper Devonian Rocks covered by Raised Beach. 1896.
1554	(Dev. 4) Near Barricane Beach, Morte Bay.	Quartz-vein in Morte Slates. 1896.
1555	(Dev. 5) Baggy Point. . .	Baggy Beds, fossiliferous. 1896.
1556	(Dev. 6) Croyde Beach. . .	Syncline in Pilton Beds. 1896.

Photographed by F. Mason Good, *Winchfield, Hants. Presented by* W. Whitaker. 11/9.

Regd. No.		
1454	Lynmouth.	Devonian Rocks on beach.
1455	„	Town and Valley of R. Lynn.
1456	East Lynn, Lynton. . . .	River erosion.
1457	„ „	„ „

Photographed by A. R. Hunt, *Southwood, Torquay.* 1/2.

408	Kent's Cavern.	Canine teeth of Wolf, Hyæna, and Machairodus.

Photographed by H. L. P. Lowe, *Shirenewton Hall, Chepstow.* 1/2.

1537	(C) Birch Tor, Dartmoor. . .	Weathering of granite. 1894.
1538	(B) Bellever Tor, Dartmoor.	„ „ 1894.
1539	(D) „ „ „	„ „ 1894.
1540	(G) West Dart, near Bellever Bridge. 1894.	River erosion in granite. 1894.
1541	(E) Lane's Gully, Dartmoor. .	'Phœnician Tin-working.' 1894.
1542	(F) „ „ „ .	„ „ 1894.

Dorset.—*Photographed by* F. Mason Good, *Winchfield, Hants.* 12/10.

409	Stair Cove and Lulworth Cove.	Contorted Purbeck and Portland Beds with characteristic landscape.
410	Stair Cove, Lulworth. . .	Contorted Purbeck and Portland Beds.

Photographed by H. W. Monckton, 10 *King's Bench Walk, Temple, E.C* 1/4.

415	(591) Tilly Whim 'Caves,' Swanage.	Portland Stone and Chert Beds. 1896.
1416	(593) „ „ „	Old working in Portland Stone. 1896.
1417	(592) Tilly Whim, Swanage. .	The Chert Beds, Portlandian. 1896.
1418	(585) Durlston Head. . .	Base of Purbeck Beds resting on Portland Stone. 1896.

Photographed by A. K. Coomara-Swamy, *Worplesdon, Guildford.*

1447	(D1) Blashenwell, near Corfe Castle.	Section in large tufa-pit. 1896. 1/1. (E.)
1551	(D2) Branksome Chine, Bournemouth.	Bournemouth Beds capped with Drift. 1/4. 1896.

Photographed by C. J. Watson, *Alton Cottage, Bottville Road, Acock's Green, Birmingham.* 1/2.

1512	(1038) The Agglestone, Studland.	Ferruginous Eocene Sandstone. 1893.

Photographed by A. Strahan, 28 *Jermyn Street, S.W.* 1/4.

1528	(38) East side of Lulworth Cove.	Purbeck Rocks, 'Broken Beds' and Cypris Limestone. 1893.

Photographed by Prof. F. J. Allen, *Mason College, Birmingham.* 1/1.

1613	(16) Cliffs west of Lyme Regis.	Lower Lias shale and limestone.

Photographed by R. LANGTON COLE, *Loughrigg, Cavendish Road, Sutton, Surrey.* 1/4.

Regd. No.		
1643	(8) Oswald's Bay, Lulworth.	Series from Portland Beds to Chalk compressed into about half a mile. 1893.

GLOUCESTER.—*Photographed by* A. K. COOMARA-SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

1547	(G1) Garden Cliff, Westbury-on-Severn.	Variegated Triassic Marls. 1897.
1548	(G4) Scar Hill, Nailsworth.	Junction of Freestones and Ragstones, Inferior Oolite. 1897.
1549	(G2) " " "	" " "
1550	(G3) " " "	" " "

HAMPSHIRE, ISLE OF WIGHT.—*Photographed by* F. MASON GOOD, *Winchfield, Hants.* 1/1.

411	Scratchells Bay.	Chalk with Flints.
1458	" "	" " "

Photographed by A. K. COOMARA-SWAMY, *Walden, Worplesdon, Guildford.* 1/1. (*E*)

1448	(I.W. 1) Between Colwell Chine and How Ledge.	Thrust-plane in How Ledge Limestone. 1896.
1449	(I.W. 2) Foreshore, Yarmouth.	Fan-palm leaf in Bembridge Marls. 1896.
1552	(I.W. 3) S. of Brightstone.	'Variegated Sandstones' of Wealden age. 1/4. 1896.

Photographed by S. H. REYNOLDS, *University College, Bristol.* 1/2.

1593	(21) Scratchells Bay.	Disturbed Upper Chalk with Flint bands. 1896.

Photographed by R. LANGTON COLE, *Loughrigg, Sutton, Surrey.* 1/4.

1636	(1) Alum Bay.	Coloured Sands. 1893.
1637	(2) " "	Cliffs and Needles. 1893.
1638	(3) Freshwater Bay.	Highly inclined Chalk. Crushed flints. 1891.
1639	(4) " "	Arched Stack of Chalk. 1891.
1640	(6) " "	Chalk Cliffs along Strike of Bedding. 1891.
1641	(5) Watcombe Bay.	Inclined Chalk; formation of Caves and Needles by Waves. 1891.
1642	(7) Headon Hill, Alum Bay.	Oligocene Strata. 1893.

KENT.—*Photographed by* Captain S. GORDON MCDAKIN, 15 *Esplanade, Dover.*

414*a*	(678) Shakespeare Cliff, Dover.	Before the Great Fall in 1897 (taken in 1895). 1/4.
1635	(892) " "	After the Great Fall in 1897 (taken February 5, 1897). 1/2. (E.)

From the Collection of the late W. TOPLEY, *F.R.S.*

1473	Encombe Tennis Lawn, Folkestone.	Fissure caused by Landslip of 1893. 1/2.
1474	East of Encombe Grounds, Folkestone.	East end of Landslip Fissure. 1893. 1/2.
1475	" "	Fissure caused by Landslip. 1893. 1/2.

Regd. No.		
1476	Undercliff between Sandgate and Folkestone.	Folkestone Beds slipped over Sandgate Beds. 1893. 1/2.
1477	Near Folkestone. . . .	Landslipped Ground. 1893. 1/2.
1478	The Warren, Folkestone. . .	„ „ „ 1/1.
1479	„ „ . .	„ „ „ „

Photographed by H. A. ALLEN, *28 Jermyn Street, S.W.* 1/4.

1494	Foreness Point, North Foreland.	Chalk showing Erosion; Vertical Cliffs and Deep Bays without Talus. 1892.
1495	Cliffs, N.E. of Margate. . .	Vertical Chalk Cliffs. 1892.

**Photographed by* Mr. D. JOHNSON, *10 Grecian Road Tunbridge Wells, under the direction of* Dr. G. ABBOTT, *2 Queen's Road, Tunbridge Wells, and presented by the latter.* 1/2. *(E.)*

1514	(601) Grove Hill Road, Tunbridge Wells.	Decoloration of Clay Bed in Tunbridge Wells Sand. 1895.
1515	(602) Boyne Park, Tunbridge Wells.	Decoloration of Tunbridge Wells Sand. 1895.
1516	(606) Rusthall Common, Tunbridge Wells.	Worn Surface of Decolorised Tunbridge Wells Sand. 1895.
1517	(607) Road from Tunbridge Wells Common to the 'High Rocks.'	Honeycombing of Tunbridge Wells Sand. 1895.
1518	(612) In Copse, near road from Tunbridge Wells Common to 'High Rocks.'	„ „ „
1522	(623) Tunbridge Wells Common.	Holes along Bedding Plane of Tunbridge Wells Sand. 1896.
1526	(631) Boyne Park, Tunbridge Wells.	Decolorised Sandstone. 1897.
1527	(632) „ „	Sandstone Decolorised beneath Soil. 1897.

LANCASHIRE.—*Photographed by* W. J. HARRISON, *52 Claremont Road, Handsworth, Birmingham. Presented by* W. WHITAKER. 1/2.

1438	Beach at Grange. . . .	Boulders of Tuff and Limestone. 1896.
1439	Grange.	Glaciated Surface of Carboniferous Limestone. 1896.

LEICESTERSHIRE.—*Photographed by* T. B. DANIEL, *Kinchley Hill, Loughborough.* 1/4.

1419	Brazil Wood, near Mount Sorrel.	Dyke of Granite in Hornfels. 1896.

Photographed by Prof. F. G. ALLEN, *Mason College, Birmingham.* 1/2.

1617	(20) Tin Meadow, near Peldar Tor, Charnwood Forest.	Agglomerate with large bombs. 1896.
1618	(21) Crag on drive to Charnwood Lodge.	Cleaved Agglomerate (pre-Cambrian). 1896.
1619	(22) „ „ „	„ „ „
1620	(23) Beacon Hill. . . .	Volcanic Ash and Hornstones. 1896.
1621	(24) Grounds of Hanging Rocks, Woodhouse Eaves, Charnwood.	Banded and Cleaved Hornstones of Woodhouse Series. 1896.
1622	(25) „ „ „	„ „ „

LINCOLNSHIRE.—*Photographed by* H. PRESTON, *the Waterworks, Grantham.* 1/4.

1413	Wilsford Cutting, G.N.R. Ancaster.	Anticline in Lincolnshire Limestone. 1896.

MONMOUTHSHIRE.—*Photographed by* H. L. P. LOWE, *Shirenewton Hall, Chepstow.* 1/2.

Regd. No.		
1544	(N) Entrance to the Severn Tunnel.	Icicles showing water-bearing stratum. 1895.
1545	(O) Shirenewton. . . .	Sink in Carboniferous Limestone. 1897.
1546	(Q) " . . .	Fracture of Carboniferous Limestone near fault. 1897.

NORFOLK.—*Photographed by* W. J. HARRISON, 52 *Claremont Road, Handsworth, Birmingham. Presented by* W. WHITAKER. 1/2.

1437	Cromer.	Mr. Savin's collection of elephant teeth. 1896.

Presented by CLEMENT REID, 28 *Jermyn Street, S.W., and Copied by* W. W. WATTS.

1650	Church Tower at Eccles. . .	In 1886, when clear of sand-dunes. 1/2.
1699	" " " . .	Copies of drawings in Lyell's 'Principles,' showing condition of Tower in 1839 and 1862. 1/4.
1700	" " " . .	

Photographed by A. STRAHAN, 28 *Jermyn Street, S.W.* 1/4.

1711	(35) Western chalk bluff, Trimingham.	Boulder clay thrust under contorted chalk. 1893.
1712	(42) Cliff at Runton. . . .	Contorted drift, with included chalk masses. 1893.
1713	(43) Cliff at Beeston. . . .	'Augen' structure in contorted drift. 1893.

NORTHUMBERLAND.—*Photographed by* E. J. GARWOOD, *Dryden Chambers, Oxford Street, W.C.* 1/1.

1450	Swine Den, Cullernose Bay. . .	Grit and shale caught up and metamorphosed by Whin Sill. 1895.
1451	Snableazes Quarry, Ratcheugh. .	Whin on Four-fathom Limestone, and intruding on the shale above it. 1895.
1452	" " " .	" " " "

NOTTINGHAMSHIRE.—*Presented by* W. WHITAKER. 1/2.

413	Berry Hill, near Mansfield Woodhouse.	Lower Mottled Sandstone covered by Pebble Beds of Trias.

**Photographed by* Messrs. J. BURTON & SONS, *Leicester.* 12/10.

1488	The Himlack Stone. . . .	Stack of Trias cemented by Sulphate of Barium. 1890.
1489	" " " . . .	" " " "
1490	Nottingham Castle Hill. . .	Bunter Pebble Beds. 1882.
1491	" " " . .	" " " "
1492	Nottingham Church Cemetery. .	Caverns in Bunter Pebble Beds. 1882.
1493	" " " .	" " " "

Photographed by Prof. F. J. ALLEN, *Mason College, Birmingham.* 1/2.

1614	(17) Berry Hill, near Mansfield Woodhouse.	Lower Mottled Sandstone. 1893.
1615	(18) Cinder Hill Brickyard, 3 miles W.N.W. of Nottingham.	Permian Marls, red and green. 1893.
1616	(19) Giltbrook, N.W. of Kimberley.	Faults in Coal-measures and in a seam of coal. 1893.

SHROPSHIRE.—*Photographed by* A. A. ARMSTRONG, *Denstone College, Staffs.* 1/2.

Regd. No.		
1420	(79) Ellesmere College. . .	Boulder. 1896.

SOMERSET.—*Photographed by* A. A. ARMSTRONG, *Denstone College, Staffs.* 1/2.

1421	12) Sedgemoor Battlefield and Polden Hills.	Escarpment of Rhætic Beds and Lower Lias. 1896.
1422	503) Cheddar Cliffs. . . .	Carboniferous Limestone. 1896.
1423	(505) „ „	„ „ „
1424	(506) „ „	„ „ „

Photographed by S. H. REYNOLDS, *University College, Bristol.* 1/2.

1585	(13) Cheddar Gorge. . . .	Influence of dip in formation of cliffs; Carboniferous Limestone. 1894.
1586	(14) „ „ . . .	„ „ „ „
1587	(15) „ „ . . .	„ „ „ „
1588	(16) Cheddar.	Screes of Carboniferous Limestone. 1894.

Photographed by Prof. F. J. ALLEN, *Mason College, Birmingham.* 1/1.

1633	(15) Cheddar Pass. . . .	Erosion of Carboniferous Limestone.
1634	(14) Cheddar Pass, Pinnacle Rock.	„ „ „

STAFFORDSHIRE.—*Photographed by* A. A. ARMSTRONG, *Denstone College, Staffs.* 1/2.

1425	(128) Dovedale, from Izaak Walton Hotel.	Carboniferous Limestone scenery. 1896.
1428	(279) Ludchurch, N. of the Roaches, near Leek.	Chasm caused by landslip in Millstone Grit. 1896.
1429	(280) „ „ .	„ „ „ „
1430	(366) The Roaches, near Leek. .	Escarpment of Third Rock, Millstone Grit. 1896.
1431	(367) „ „ .	„ „ „ „
1432	(368) „ „ .	„ „ „ „
1433	(369) „ „ .	„ „ „ „
1434	(365) „ „ .	„ „ „ „
1435	(370) „ „ .	„ „ „ „
1610	(537) The Weaver Hills. . .	Pockets in Carboniferous Limestone filled with sand, clay, and gravel. 1897.
1611	(538) „ „ . .	„ „ „ „
1612	(539) „ „ . .	„ „ „ „

Photographed by H. W. MILNE, *Barnet.* 1/2.

1426	(M.11) R. Manifold, near Wetton.	Swallow of River in Carboniferous Limestone. 1896.
1427	(M.13) Thor's Cave „ „	Dry bed of River Manifold. 1896.

SUFFOLK.—*Photographed by* J. D. HARDY, 73 *Clarence Road, Clapton, N.E. Presented by* W. WHITAKER. 1/4.

1453	South end of Covehithe Cliff, Southwold.	Marine denudation of Newer Pliocene strata; overhanging soil very marked.

SURREY.—*Photographed by* A. E. MURRAY, *St. Clare, Upper Walmer, Kent.* 1/4.

1459	Lane between Shottermill and Hindhead, Haslemere.	Fault in Lower Greensand. 1895.

**Photographed by* D. JOHNSON, 10 *Grecian Road, Tunbridge Wells, under the direction of* Dr. G. ABBOTT, *and presented by him.* 1/2. (*E*)

Regd. No.		
1519	(613) Sand Quarry, Oxted. . .	Tubular ferruginous concretions in Folkestone Beds. 1895.
1520	(614) " " . .	" " " "
1521	(615) " " . .	" " " "

Photographed by W. W. WATTS, 28 *Jermyn Street, S.W.* 1/4.

1531	(250) Leith Hill. . . .	Lower Greensand escarpment. 1896.
1532	(251) " . . .	Lower Greensand landscape. 1896.
1533	(252) " . . .	Chert beds in Hythe Series. 1896.
1534	(254) Lane from Collickmoor Farm to Dorking.	Ironstone lumps in Hythe Series. 1896.

Photographed by R. LANGTON COLE, *Loughrigg, Sutton, Surrey.* 1/4.

1644	(9) Leith Hill. . . .	Escarpment of Hythe Beds, Lower Greensand, 1891.

SUSSEX.—*Photographed by* W. J. LEWIS ABBOTT, *Seale House, The Vine, Sevenoaks.* 1/2.

1444	Hastings.	Kitchen Midden. 1895.

Photographed by W. T. FLOWERS, *under the direction of* Dr. G. ABBOTT, 2 *Queen's Road, Tunbridge Wells.* 1/2. (*E*)

1523	(624) Eridge Rocks, Tunbridge Wells.	Honeycombing along lines of false-bedding in Tunbridge Wells Sand. 1896.

**Photographed by* D. JOHNSON, 10 *Grecian Road, Tunbridge Wells, under* Dr. ABBOTT'S *direction.* 1/2. (*E*)

1524	(626) Cumberland Walk, Tunbridge Wells.	Angular blocks of sandstone in bed of clay. 1896.
1525	(628) " " " .	" " " "

Photographed by A. R. PERRY, 13 *Wellington Place, Hastings. Presented by* P. H. PALMER. 11/8.

1646	West Quarry, West Hill, Hastings, near the Castle.	Jointing and bedding in Ashdown Sand.
1647	" " "	" " " "
1648	" " "	" " " "
1649	" " "	" " " "

WARWICK.—*Photographed by* W. J. HARRISON, 52 *Claremont Road, Handsworth, Birmingham. Presented by* W. WHITAKER. 1/2.

1440	California, near Birmingham. .	Boulder Clay. 1892.
1441	" " " .	" "
1442	Moseley " " . .	Glacial Sands, 40 feet.
1443	Dosthill.	Cambrian Shales.

WESTMORELAND.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds. Sent through the* YORKSHIRE NATURALISTS' UNION. 1/2.

1628	(3379) Sourmilk Gill, Easedale, Grasmere.	Waterfall over Borrowdale Rocks. 1895.

YORKSHIRE.—*Photographed by* MR. ALLERSTON. *Presented by* G. W. LAMPLUGH, 28 *Jermyn Street, S.W.* 1/2.

Regd. No.		
1460	Sewerby Cliff, near Bridlington Quay.	Cliff of chalk, sea-beach, and land-wash, all pre-Glacial.

Photographed by F. N. EATON, 1 *Higher Lane, Aintree, Liverpool.* 1/4.

1480	R. Doe, Ingleton.	Near the Craven fault; ancient rocks.
1481	„ „	„ „ „ „

Photographed by J. HORT PLAYER, 16 *Prince Arthur Road, Hampstead, N.W.* 1/2.

1535	Egton Bridge.	Cleveland Dyke; two types of dolerite.
1536	„ „	„ „ „ „

Photographed by S. H. REYNOLDS, *University College, Bristol.* 1/2.

1579	(7) Gordale Scar. . . .	Ravine in Carboniferous Limestone. 1889.
1580	(8) Malham Cove. . . .	Cliff of Carboniferous Limestone. 1889.
1581	(9) Moughton, near Settle. .	Carboniferous Limestone resting unconformably on Coniston Grits. 1889.
1582	(10) Pen-y-ghent, from Horton Station.	Hill of circumdenudation, Yoredale Beds and Millstone Grit. 1889.

Photographed by H. PERCY, *Doncaster. Sent through the* YORKSHIRE NATURALISTS' UNION. 1/2.

1470	(1) Railway cutting, near Marr, W. of Doncaster.	Anticline in Magnesian Limestone. 1897.
1471	(2) „ „ „	„ „ „ „
1472	(3) „ „ „	„ „ „ „
1487	„ „ „	„ „ „ „

Photographed by S. W. CUTTRISS, 6 *Fieldhead Terrace, Camp Road, Leeds. Sent through the* LEEDS GEOLOGICAL ASSOCIATION.

1500	Alum Pot, Ribblesdale. . .	Caves and widened joints in Carboniferous Limestone; Stalactites.
1501	Entrance to Brow Gill Cave, Ribblesdale.	„ „ „ „
1502	Interior of Brow Gill Cave. .	„ „ „ „
1503	Hull Pot, Ribblesdale. . .	„ „ „ „
1504	Hunt Pot, „ . . .	„ „ „ „
1505	Troller's Cave (Hell Hole), Wharfedale.	„ „ „ „
1506	Rowten's Pot, Kingsdale. . .	„ „ „ „
1507	Goyden Pot, Nidd Valley. . .	„ „ „ „
1508	„ „ . .	„ „ „ „
1509	Gaping Gill, Ingleborough. .	„ „ „ „
1510	„ „ . .	„ „ „ „

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds. Sent through the* YORKSHIRE NATURALISTS' UNION. 1/2.

1568	(4076) Hardraw Scar, near Hawes.	Yoredale Rocks; Waterfall. 1897.
1569	(4077) „ „	„ „ „
1570	(4078) „ „	„ „ „
1571	(4051) Walden Force, West Burton Aysgarth.	Yoredale Series. 1897.

Regd. No.		
1572	(4064) Aysgarth Force (lower), River Ure, Wensleydale.	Yoredale Series. 1897.
1629	(1767) Banks of River Nidd, below Knaresborough.	Magnesian Limestone resting unconformably on Millstone Grit. 1891.
1630	(3784) North side of Selwick Bay, Flamborough.	Chalk. 1896.
1631	(3749) Gristhorpe Nab, near Filey.	Corallian Rocks on Oxford Clay. 1896.
1632	(3764) Robinhood's Bay. . .	Lias. 1896.

WALES.

CARNARVONSHIRE.—*Photographed by* G. T. ATCHISON, *Corndon, Sutton, Surrey.* 1/4.

827	Yr Eifl (The Rivals), Nevin Bay.	Igneous intrusions in Ordovician Rocks. 1895.

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds. Sent through the* YORKSHIRE NATURALISTS' UNION. 1/2.

1496	(3972) Y Foel Perfedd, near Pen-y-Pass, Llanberis.	Perched Block. 1896.
1497	(3970) " "	" " 1896.
1498	(4000) Penrhyn Slate Quarries. .	Llanberis Slates. 1896.
1499	(4001) " " "	" " 1896.
1623	(3999) Pass of Nant Ffrancon. .	Ordovician Rocks. 1896.
1624	(3943) " " " .	" " 1896.
1625	(3992) Head of Nant Ffrancon.	" " 1896.
1626	(3950) Llyn Idwal, Twll Du, and the Glyders.	" " 1896.
1627	(3958) Head of Llyn Idwal. .	Storm in the Devil's Kitchen. 1896.

GLAMORGANSHIRE.—*Photographed by* A. A. ARMSTRONG, *Denstone College, Staffs.* 1/2.

1436	(110) Mumbles Head, Swansea.	Carboniferous Limestone. 1896.

Photographed by R. H. TIDDEMAN, 28 *Jermyn Street, S.W.* 1/2.

1697	Southerndown, near Bridgend. .	Lower Lias resting unconformably on Carboniferous Limestone. 1897.
1698	" " "	" " "

MERIONETHSHIRE.—*Photographed by* G. J. WILLIAMS, *Bangor.* 1/2.

603*c*	Foel Tan-y-Grisiau. . . .	Granitite intrusive into Tremadoc Rocks.

Photographed by J. W. REED, 17 *Colebrooke Row, Islington, N. L.*

1564	Dolgelly.	Cambrian and Ordovician Landscape.
1565	Cwm Bychan Lake. . . .	Cambrian Rocks.
1566	The Roman Steps, Drws Ardudwy.	" "
1567	" " " "	" "

MONTGOMERYSHIRE.—*Photographed by the late* REV. D. J. MACLEOD, *Hope, Salop.* 1/2.

703	The Roundtain from the S. .	Arenig Volcanic Rocks.

PEMBROKESHIRE.—*Photographed by* H. L. P. LOWE, *Shirenewton Hall, Chepstow.* 1/2.

1543	(A) Caldy Island, near Tenby. .	Vertical Carboniferous Limestone. 1895.

RADNORSHIRE.—*Presented by* W. WHITAKER. 9/7.

Regd. No.		
1559	Caban Coch, Birmingham Waterworks Scheme.	Silurian Grits.

THE CHANNEL ISLANDS.

JERSEY.—*Photographed by* S. H. REYNOLDS, *University College, Bristol.* 1/2.

1583	(11) South Hill Quarry, St. Heliers.	Lamprophyre Dyke intrusive in Granophyre. 1896.
1584	(12) East of Corbière Point.	Marine denudation of Granite. 1896.

SARK.—*Photographed by* F. MASON GOOD, *Winchfield, Hants.* 10/8.

412	Rocks at Port du Moulin.	

ISLE OF MAN.

Photographed for DR. A. HAVILAND, *Douglas. Presented by* G. W. LAMPLUGH. 1/1.

1461	North end of Douglas Bay. .	Lonan Flags (Skiddaw Series).
1462	Prospect Hill, opposite the House of Keys, Douglas.	Glacial Beds.
1463	Poortown, West Quarry. . .	Boulder of Diabase.

Photographed by S. H. REYNOLDS, *University College, Bristol.* 1/2.

1589	(17) Langness, near Castletown.	Basement Carboniferous Sandstone, resting unconformably on 'Skiddaw Slate'; both faulted. 1893.
1590	(18) Pooylvaaish, near Castletown.	Marine Denudation of Carboniferous Limestone; 'reef-knolls.' 1893.
1591	(19) Stack of Scarlett, near Castletown.	Sea-stack of augite-andesite. 1893.
1592	(20) Port Erin Harbour, North side.	Contorted 'Skiddaw Slate.' 1893.

Photographed by W. W. WATTS, 28 *Jermyn Street, S.W.* 1/4.

1763	(M 10) Langness, near Castletown.	Carboniferous Conglomerate. 1897.
1762	(M 23) Glen Wyllin. . . .	Re-excavation of Drift-filled Valley by Stream. 1897.

SCOTLAND.

ARGYLL.—*Photographed by* DR. R. D. ROBERTS, *Clare College, Cambridge.* 1/4.

1464	(1) The Sgurr of Eigg, E. . .	Shape of Sgurr. 1896.
1465	(2) ,, ,, from S. .	Pitchstone resting on Basalt sheets. 1896.
1466	(3) ,, ,, . . .	Pitchstone. 1896.
1467	(4) ,, ,, . . .	Cave at junction of Pitchstone and Basalt with old river-gravel between. 1896.
1468	(5) ,, ,, Spur branching to N.	Columnar Pitchstone. 1896
1469	(6) ,, ,, top of .	,, ,,

Photographed by W. NORRIE, *Fraserburgh.* 1/1.

1529	(8) Sgurr of Eigg. . . .	Pitchstone.

Photographed by W. LAMOND HOWIE, *Monton House, Monton, Eccles, N.B.* 14/4.

Regd. No.		
1761	( ) Beinn Nevis from Carn Mor Dearg.	View of mountain.

BANFF.—*Photographed by* A. S. REID, *Trinity College, Glenalmond, N.B.* 1/2.

1758	(H.P. 109) W. of Gardenstown.	Fault between Old Red Sandstone and Metamorphic Series. 1897.

ELGIN.—*Photographed by* W. LAMOND HOWIE, *Monton House, Monton, Eccles.* 1/1. (*E*)

1760	( ) Speyside, near Fochabers. .	Earth pillars in Old Red Sandstone conglomerate.

INVERNESS.—**Photographed by* W. NORRIE, *Fraserburgh.* 1/1.

1530	(1) Corrie Laggan, Skye. . .	Glaciation.

**Photographed by* G. P. ABRAHAM, *Lake Road, Keswick. Presented by* W. W. WATTS. 1/1.

1701	(15) Sgurr na Gillean, Pinnacle Route.	Craggy form of Tertiary gabbros. 1896.
1702	(23) Sgurr na Gillean; the Gendarme.	Weathering of gabbro along joints and double basic dyke. 1896.
1703	(12) Glamaig, from Sligachan. .	Cone of Granophyre. 1896.

PERTH.—*Photographed by* A. R. HUNT, *Southwood, Torquay.* 1/2.

432	Near Rumbling Bridge, Dunkeld .	River-worn rocks.

IRELAND.

ANTRIM.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/1.

1594	(5152) Murlough Bay. . .	Ancient Rocks, Trias, and Chalk. 1897.
1595	(5154) " " . .	Conglomerate at base of Cretaceous System, resting on Trias. 1897.
1596	(5155) " " . .	
1651	(1175) Cooraghy Bay, Rathlin Island.	Excavated out of Chalk and Basalt. 1891.
1652	(969) The Grand Causeway. .	Columnar and cup-and-ball Basalt. 1893.
1653	(253) Giant's Eyeglass. . .	Erosion of cliffs of columnar Basalt. 1885.
1654	(5119) Whitepark Bay. . .	Storm action on Chalk. 1895.
1655	(1173) Runabay Head and Portaleen Bay, Torr.	Hornblende-schists and gneisses. 1889.
1656	(588) Cushendun. . . .	Caves in Old Red Conglomerate. 1886.
1657	(549) Ess-na-Larach, Glenariff.	Gorge and waterfall in vesicular basalt.
1658	(5151) Squire's Hill, Belfast. .	Contact of Chalk and Basalt. 1896.
1659	( ) Bay, near Kilroot. . .	Eroded in soft Trias which forms landslips. 1896.
1660	(5118) Waterfall at Ballyrudder.	Glacial Sands and Gravels.
1714	(5112) Ramore Head, Portrush.	Lias shales intruded upon and altered by dykes. 1895.
1715	(5113) Portrush. . . .	Lias shales cut by Tertiary dyke. 1895.
1716	(5126) Shore at Golf Hotel, Portrush	Peat under sand-dunes. 1895.
1717	(258) Portmoon. . . .	Columnar Basalt and dyke. 1886.

Regd. No.		
1718	(360) The Corn Sacks, Ballygally Head.	Coarsely columnar dolerite.
1719	(5105) Whitewell, Belfast. .	Pockets of altered flints between Basalt and Chalk. 1892.
1720	(5109) Whitehead Quarry, near Carrickfergus.	Boulder Clay on glaciated surface of Basalt and Chalk. 1896.
1721	(961) Portaleen Bay. . .	Schists. 1891 or 1892.
1722	(295) Curran of Larne. . .	Raised beach. 1886.
1723	(5130) „ „ . .	The Larne Gravels. 1889.
1724	(5122) Moylena, Antrim. . .	Glacial Sands and Gravels. 1895.
1725	(5123) „ „ . .	„ „ „

Photographed by J. St. J. Phillips, 20 *University Square, Belfast. Sent through* Belfast Naturalists' Field Club. 1/2.

1597	(214) Tardree Quarry, S. side. .	Columnar structure in rhyolite. 1895.
1598	(215) Sandy Braes. . . .	Rhyolite decomposing into sand. 1895.
1599	(216) Squire's Hill, N. of Belfast.	Tabular flints, faults, and dykes in the Chalk. 1896.
1600	(217) „ „ „	Dyke in Chalk. 1896.
1601	(218) „ „ „	Dyke in Chalk, including a mass of chalk. 1896.
1602	(219) Kilcoan, Island Magee. .	Edge of dyke through the Brown Sands. 1896.
1603	(220) Cave Hill Quarry, Belfast, W. end.	Dyke in Chalk. 1896.
1608	(225) Crow Glen, Belfast. .	Chloritic Chalk and Sands. 1897.
1609	(226) Glenoe, near Larne. .	Cretaceous Rocks covered by Glacial beds 1896.

Cavan.—**Photographed by* R. Welch, *Lonsdale Street, Belfast. Sent through* Belfast Naturalists' Field Club. 1/1.

1744	(5138) Blacklion. . . .	Erratic of Millstone Grit.

Clare.—**Photographed by* R. Welch, *Lonsdale Street, Belfast. Sent through* Belfast Naturalists' Field Club. 1/1.

1661	(5131) The Burren district. .	Terraces of Carboniferous Limestone. 1895.
1662	(5133) „ „ „ . .	„ „ „ „
1663	(5134) „ „ „ . .	Limestone Talus covering terraces.

Donegal.—**Photographed by* R. Welch, *Lonsdale Street, Belfast. Sent through* Belfast Naturalists' Field Club. 1/1.

1664	(1472) Muckros 'Market House.'	Bedding and jointing in Carboniferous Limestone. 1890.
1665	(2212) The 'Seven Arches' Portsalon.	Bedded quartzites. 1893.
1666	(1386B) The Pullins, Ballintra. .	Underground river channel in Carboniferous Limestone. 1894.
1726	(2271) Muslac Cliffs, Rosapenna.	Contorted quartzites.
1727	(5142) Moross Ferry, Portsalon.	Contorted schists. 1894.
1728	(5143) Moross Castle, Mulroy Bay.	Overthrust fold with pinching out of middle limb. 1894.
1729	(2207) Three Mouth Cave, Portsalon.	Quartzite cliffs. 1893.
1730	(2215) Port Leaca, Portsalon. .	Stacks of Quartzite. 1893.
1731	(2222) Great Cave, Portsalon. .	Arches of bedded Quartzite. 1893.
1732	(2246) Mulroy Bay, near Head. .	Schistose rocks. 1893.
1733	(1351) Glen Columbkill. . .	Metamorphic rocks and estuarine deposits. 1890.

Regd. No.		
1734	(1357) Glen Head. . . .	Cloud Banner. 1890.
1735	(1359) The Sturrell, Glen Head.	Quartzite and dykes. 1889.
1736	(1485) Teelin Salmon Rapids. .	River erosion in schists. 1890.
1737	(5136) Bundoran. . . .	Rain sculptured boulder clay. 1894.
1738	(1398) West end of Bundoran. .	Bedded Carboniferous rocks. 1894.
1739	(1399) " " " . .	" " "
1740	(1393) The Fairy Bridges, Bundoran.	Sea-worn caves in Carboniferous Limestone with the roofs falling in. 1892.
1741	(1394) " " "	" " " "
1742	(1386) The Pullins, Ballintra, Ballyshannon.	Underground river channel in Carboniferous Limestone. 1894.
1743	(5137) Piper's Cave, Pullins, Ballintra.	Cave with stalagmites and stalactites. 1894.

DOWN.—*Photographed by* MISS M. K. ANDREWS, 12 *College Gardens, Belfast.* 12/10. (*E*)

1513	(1) Glen River, Newcastle Demesne.	Junction of Ordovician Rocks with granite; basalt dyke cut off by latter.

Photographed by J. ST. J. PHILLIPS, 20 *University Square, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/2.

1604	(221) Scrabo Quarry, Newtonards.	Sills cut through by dyke of dolerite. 1897. 1/4.
1605	(222) " " "	" " " "
1606	(223) " " "	" " " "
1607	(224) " " "	Dolerite dyke with sills branching out from it. 1896.

**Photographed by* R. WELCH, *Lonsdale Street, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/1.

1667	(716) The 'Butterlump,' near Newtonards.	Erratic of basalt weighing about 133 tons. 1892.
1668	(1552) The Happy Valley and Slieve Lough Shannagh, Mourne Mountains.	Valley eroded in granite and floored with alluvium. 1895.
1669	(1554) " " "	" " " "
1749	(759) Slieve Donard from Slieve Bingian, Mourne Mountains.	Weathering of granite. 1889.
1750	(752) Castles of Kivvitar, Mourne Mountains.	Weathering of well-jointed granite. 1890.
1751	(767) " " "	Weathered granite stacks. 1890.
1752	(5115) Glasdrumman, Newcastle.	Composite dyke. 1895.
1753	(5116) " "	" " "
1754	(5117) " "	" " "

DUBLIN.—*Photographed by* S. H. REYNOLDS, *University College, Bristol.* 1/2.

1573	(1) Portraine, and Lambay Island.	Crushed Bala Beds. 1894.
1574	(2) Portraine.	Ordovician or Silurian grits and slates. 1894.
1575	(3) "	Overfolded Bala Limestone and Shale. 1894.
1576	(4) "	" " "
1577	(5) "	Bala Limestone. 1894.
1578	(6) Above Saltpan Bay, Lambay Island.	Beginning of landslip. 1895.

Photographed by R. LANGTON COLE, *Loughrigg, Sutton, Surrey.* 1/4.

Regd. No.		
1645	(10) Coast of Howth. . .	Cambrian Rocks. 1892.

**Photographed by* R. WELCH, *Lonsdale Street, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/1.

1670	(5150) N. of Bray Harbour. .	Submerged peat with tree-stumps *in sitû.* 1896.
1745	(1603) Howth Head. . . .	Cambrian Quartzite and Slate. 1889.

FERMANAGH.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1. *Sent through* BELFAST NATURALISTS' FIELD CLUB.

1746	(1834) Knockmore, Enniskillen.	High cliffs of Carboniferous Limestone. 1890.

GALWAY.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/1.

1671	(5144) Benlettery, Connemara. .	Jointed pre-Silurian Quartzite. 1896.
1672	(2139) Benbreen and Bengower from Benlettery.	Quartzite crags. 1895.
1673	(2124) *Col* between Bengower and Benbreen.	Pre-Silurian Quartzites. 1895.
1674	(2120) Summit of Benbreen. .	Scarped face of Quartzites with talus at foot. 1896.
1675	(5145) Summit of Bengower. .	Scarp of pre-Silurian Quartzite. 1895.
1676	(2144) Kylemore Pass, Lake and Diamond Mountain.	Valley in schists and quartzite. 1894.
1677	(2141) Cashel Mountain, Connemara.	Granite and schist with basic intrusions. 1894.
1678	(2118) Derryclare Mountain, from vale of Inagh.	Glaciated quartzites. 1894.
1679	(2121) Derryclare Mountain and Lough.	" " "
1680	(2123) Derryclare Lough and Ben Corbeg.	" " "
1681	(5146) Macdara's Island. . .	'Block-beach' of granite fragments. 1896.
1682	(5147) Roundstone. . . .	'Block-beach' of granite fragments. 1896.
1683	(5148) " . . .	Partly submerged peat beds. 1896.
1684	(2353) Dog's Bay and Urrisbeg Mountain, Connemara.	Glaciated granite; beach of broken shells and foraminifera. 1895.
1755	(5129) Dog's Bay, Roundstone. .	Kitchen Midden, *Purpura lapillus.* 1895.
1756	(5128) " " "	" " *Littorina* "
1757	(5127) " " "	" " *Patella* "

Photographed by H. L. P. LOWE, *Shirenewton Hall, Chepstow.* 1/2.

1482	(H) Lough Muck, Connemara. .	Glacier-worn rocks. 1889.
1483	(I) " " "	" " " "
1484	(J) " " Mouth of .	Relation of rocks, bog, and sea. 1889.
1485	(K) " " "	" " " "
1486	(L) Ross Row, Little Killery, Connemara.	Metamorphic rocks. 1889.

LONDONDERRY.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/1.

1685	(1742) North entrance to Gorge R. Roe, Limavady.	Excavated in schists. 1896.
1686	(1744) The Dog's Leap, R. Roe, Limavady.	" " 1895.

Regd. No.		
1687	(1749) Gorge of R. Roe, Limavady.	Excavated in schists. 1896.
1688	(1750) Southern entrance to Gorge of R. Roe, Limavady.	" " "
1689	( ) Glens of Banagher.	" " "
1690	( ) " "	" " "

MAYO.—*Photographed by* R. WELCH, *Lonsdale Street, Belfast. Sent through* BELFAST NATURALISTS' FIELD CLUB. 1/1.

1691	(5170) Minaun Cliffs, Achill Island.	Flaggy micaceous quartzite. 1897.
1692	(5171) " " " .	Overfolded quartzites. 1897.
1693	(5172) Cathedral Caves, Achill Island.	Marine erosion of flaggy quartzites. 1897.
1694	(5173) " " " .	" " " "
1695	(5199) 'Gulf' of Aille, Westport.	Subterranean river in Carboniferous Limestone, 1897.
1696	(5200) " " " .	

SLIGO.—*Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

1747	(5141) Aughros Head. . .	Lower Carboniferous strata. 1892.
1748	(5140) " " . .	" " " "

ROCK STRUCTURES, &c.

Photographed by H. PRESTON, *Grantham.* 1/4.

1414	( ) Near Swanage, Dorset. .	*Chara*-chert from Purbeck Beds. 1896.

Photographed by W. W. WATTS, 28 *Jermyn Street, S.W.* 1/4. (*L*)

1704	(183) Pondfield Bay, near Swanage, Dorset.	*Chara*-chert from Purbeck Beds. 1896.
1705	(184) " "	" " " " "
1706	(186) " "	" " " " "
1707	(187) " "	" " " " "
1708	(18) Spilsby, Lincoln. . .	Sandstone.
1709	(162) Cheviots, Northumberland.	Granite.
1759	(133) Mexico.	Perlitic structure in obsidian.

Photographed by J. J. H. TEALL, 28 *Jermyn Street, S.W.* 1/4.

1710	Leckhampton Hill, Gloucester. .	Inferior Oolite.

Photographed by A. R. HUNT, *Southwold, Torquay.* 1/4.

1511	Rydonball Cross, Devon. . .	Radiolarian Chert (culm ?) in Culm Conglomerate.

LIST 2.

REPLACEMENTS.

The following photographs which were missing from the collection have been replaced by the donors named :—

CHESHIRE.—C. A. DEFIEUX, 50 *Windsor Road, Tue Brook, Liverpool.* 1/2.

460	Leasowe Shore.	Blown sands showing stratification and results of wind erosion in sandhills. 1891.
461	" "	
462	Dove Point, Leasowe Shore .	Submarine Forest-bed, general view.
463	(4) " " " .	" " "
464	(5) " " " .	" " "

DERBYSHIRE.—G. BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Regd. No.		
477	(1293) Dovedale. . . .	Erosion of Carboniferous Limestone.
483	( ) "	" " "

DORSET.—Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* 1/4.

299	Lulworth Cove.	Purbeck Beds.

LANCASHIRE.—R. G. BROOK, *Wolverhampton House, St. Helen's.*

285	Ravenhead.	Coal-measures, including 'Fiery Mine' Seam.
286	"	" " " "
287	"	" " " "
288	"	" " " "
289	"	" " " "
290	"	" " " "

This set forms a continuous series.

YORKSHIRE.—G. BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

1146	(3002) Trow Gill, Clapham. .	Channel in Carboniferous Limestone.

MONTGOMERY.—W. W. WATTS, 28 *Jermyn Street, S.W.* 1/2. (*E*)

88	(12A) Corndon Hill, S.E. . .	Base of the laccolite. 1885.
89	(12) " " " . .	" " "
90	(13) Corndon Hill, W. side. .	Middle Arenig shales resting conformably on the dolerite of the laccolite. 1885.

AYRSHIRE.—J. STEWART,* 32 *Boyd Street, Largs, Ayrshire.* 1/4.

404	Loch Doon.	Glaciated surface (rock-basin).

KIRKCUDBRIGHT.—J. STEWART, 32 *Boyd Street, Largs, Ayrshire.* 1/4.

348	Ness Glen, Doon Water, near Dalmellington.	River erosion, 1891.

LANARKSHIRE.—W. W. WATTS (*Photographed by* R. MCF. MURE,* 35 *Underwood, Paisley*). 1/2.

33	Whiteinch, Partick, Glasgow. .	Fossil Forest in Coal-measures.
34	" " " .	" " "
35	" " " .	" " "

STIRLING.—J. STEWART,* 32 *Boyd Street, Largs, Ayrshire.* 1/4.

405	Strathblane.	'Ballagan Beds,' with fault in Limestone.
406	Spout of Ballagan, Ballagan Glen.	" "

DOWN.—Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* 1/4.

1000	(2) Glen River, Newcastle Demesne.	Junction of Ordovician with granite and basalt dyke cut off by latter.

FERMANAGH.—R. WELCH,* *Lonsdale Street, Belfast.* 1/1.

253	Knockmore, Enniskillen. . .	Ossiferous Cave.

ROCK-STRUCTURES.—Dr. H. STOLTERFOTH, 1 *Grey Friars, Chester.* (*L*)

700	Denbighshire.	Foraminifera, &c., in Denbigh (Carboniferous) Limestone.

LIST 3.

CORRECTIONS.

Owing to loss, withdrawal, confusion of numbering, or double entry, the following photographs have been renumbered and rearranged, or else described in more accurate detail, generally by the kind aid of the original donors. Photographs marked with these numbers in previous lists must be cancelled.

By J. STEWART,* 32 *Boyd Street, Largs.* 1/2.

Regd. No.		
28	Bute, Cumbrae; the Lion Rock.	Trap Dyke (formerly 353).

By R. WELCH,* *Lonsdale Street, Belfast.* 1/1.

50	Antrim, Whitepark Bay.	Arch of Chalk.
51	Fermanagh. Knockmore Bone Cave.	(Formerly 958a).

By R. G. BROOK, *Wolverhampton House, St. Helen's.* 1/1.

52	Denbigh. Llandulas, near Abergele.	Carboniferous Limestone (formerly 888).
57	Montgomery, Pistyll Rhaiadr.	Waterfall over Ordovician Rocks (formerly 889).

By A. O. WALKER, *Nant-y-Glyn, Colwyn Bay.* 1/2.

53	Denbigh, Cefn Beuno, Vale of Clwyd.	Caves.

By A. E. NICHOLS, 49 *Reginald Terrace, Leeds.* 1/2.

159	(G 34) York, Garforth.	Magnesian Limestone. 1889.
160	(G 34a) ,, ,,	,, ,, ,,
161	(G 36a) ,, S. Milford.	,, ,, ,,
162	(G 36) ,, ,,	,, ,, ,,
163	(G 30b) ,, Garforth.	,, ,, ,,
164	(G 30a) ,, ,,	,, ,, ,,

By WILBERT GOODCHILD, 2 *Dalhousie Terrace, Edinburgh.* 1/2.

191	Edinburgh, Salisbury Craigs.	Dolerite.

By C. J. WATSON, *Alton Cottage, Bottville Road, Acock's Green, Birmingham.* 1/1.

319	Carnarvon,	Blaen-y-nant, Llanberis.	Perched Blocks on a glaciated surface.
321	,,	Y Foel Perfedd, Llanberis.	,, ,, ,, ,,
320	,,	,, ,, ,,	Perched Block.
322	,,	Moor S. of Capel Curig.	Glaciated Rocks.
323	,,	,, ,, ,,	Roche moutonnée.
324	,,	W. side, Cwm Tryfaen.	Large perched block on glaciated surface.
325	,,	Trefriew.	Glaciated surface.

By J. STEWART,* 32 *Boyd Street, Largs.* 1/2.

404	Ayr, Loch Doon.	Glaciated surface (rock-basin) (formerly 350)
405	Stirling, Strathblane.	Ballagan Beds, with fault (formerly 351).

By A. R. HUNT, *Southwood, Torquay.*

Regd. No.		
407	Devon, Kent's Cavern. . .	5 Pecten shells cemented together. 6/6.
429	„ Lower Dunscombe Quarry, Chudleigh.	Upper Devonian rocks. 1/1.
432	Perth, Rumbling Bridge, Dunkeld.	River erosion. 1/2.

By C. A. DEFIEUX, 50 *Windsor Road, Tue Brook, Liverpool.* 1/2.

460	Leasowe Shore.	Bedding and wind-action in sand-dunes.
461	„ „	„ „ „ „ „
462	Dove Point, Leasowe. . . .	Submerged Forest-bed; general view.
463	„ „ „	„ „ „
464	„ „ „	„ „ „
465	„ „ „	„ „ „
466	„ „ „	„ „ „
467	„ „ „	„ „ tree 2 feet in diameter.

By GODFREY BINGLEY, *Thorniehurst, Headingley.* 1/2.

468	(1243)	Derby, Scarthin Nick, Matlock Bath.	Carboniferous Limestone.
469	(1319)	„ Dovedale. . .	„ „
470	(1329)	„ „ . . .	„ „
471	(1301)	„ High Tor, Matlock.	„ „
472	(1320)	„ Dovedale. . .	„ „
473	(1330)	„ „	„ „
474	(1325)	„ „	„ „
475	(1297)	„ Chee Tor, Miller's Dale.	„ „
476	(1298)	„ Chee Dale. . .	„ „
477	(1293)	„ Dovedale.	„ „
478	(1299)	„ Chee Dale. . .	„ „
479	(1313)	„ Monsal Dale. . .	„ „
480	(1326)	„ Pillar Rock, Dovedale.	„ „
481	(1300)	„ Ashwood Dale. .	„ „
482	(1322)	„ Pillar Rock, Dovedale.	„ „
483		„ Dovedale. . . .	„ „

By E. J. GARWOOD, *Dryden Chambers, Oxford Street, W.C.* 1/1.

900	Durham, Parson Byers' Quarry, Stanton-in-Weardale.	Main Limestone covered by shale. (formerly 621a).

By Messrs. STEWART & Co., **Photographers, Myrtle Street, Glasgow.* 1/1.

939	Lanark, Partick, Glasgow. . .	Fossil forest in Coal-measures. Stigmarian roots and stems.

LIST 4.

THE DUPLICATE (LOAN) COLLECTION.

The numbers placed after the description of the photograph refer to the list of names and addresses given at the end. The first number refers to the photographer who is also the donor in most cases. When he is not so the donor is indicated by a second number.

Full localities and descriptions are given in present and previous lists under the numbers.

This collection is arranged geologically, and from time to time the less perfect and less typical photographs will be removed and better ones substituted as they are given. Those laid aside can always be seen, sent, or returned by request.

* Indicates that prints and slides may be bought from the photographer. P. indicates prints. S. indicates slides.

Examples of Different Rocks.

1763	Conglomerate.	Carboniferous, Langness, Isle of Man. 1 P.
1708	Sandstone.	Neocomian, Spilsby, Lincoln. 1 P.
1709	Granite.	Cheviots. 1 P.
576	Granite.	Dewerstone, Dartmoor. 6 S.
863	Limestone.	Carboniferous, Dinder Wood, Mendips. 2 P.
137	„	„ Great Orme's Head. 3 S.
700	„	„ Denbigh. 4 P. S.
163	Magnesian Limestone.	Permian, Garforth. 5 P.
1282	Hornstones.	Pre-Cambrian, Charnwood Forest. 1 P. S.

Rock-Structures.

Bedding.

295	Coloured Marls.	Trias, Tewkesbury. 7 P.
1528	Limestones and 'Broken Beds.'	Purbeck, Lulworth. 8 P.
960	Limestones and shales.	Carboniferous, Muckros Head. 9 P.*
1199	Limestone.	„ Malham Cove. 3 S.
1352	Calcareous Grits on Oxford Clay.	Gristhorpe Cliff. 3 P.

False-bedding.

1563	Sandstone.	Trias, Hilbre Island, Cheshire. 10 P. S.
1	„	The Sphinx, Egypt. 11 P.

Fossils in Rocks.

1710	Limestone, weathered.	Inferior Oolite, above Pea Grit, Leckhampton Hill. 12 P. S.
965	Trees in Peat bog.	Armoy, Antrim. 9 P.*
467	Trees in Submerged Forest.	Leasowe, Cheshire. 10 P. S.
154	Tree in Coal-measures.	Castleford, Yorkshire. 5 P.
155	„ „	„ „ 5 S.
33	„ „	Partick, Glasgow. 42* 1 P. S
35	„ „	„ „ 42* 1 P.
34	„ „	„ „ 42* 1 S.
939	Trees „	„ „ 47* 1 P.

Concretions.

523	'Doggers' in sandstone.	Corallian, Scarborough. 5 P.

Evidences of Earth-movement.

Elevation and Submergence.

424	Raised beach.	On Devonian rocks, Hope's Nose, Torquay. 13 P.
465	Submerged forest.	Leasowe Shore, Cheshire. 10 P. S.

Folding and Contortion.

369	Anticline.	Carboniferous Limestone, Sedbergh 14 P.
879	„	„ „ Chepstow. 41 P.

Regd. No.		
39	Anticline.	Carboniferous Limestone, Draughton, Yorkshire. 15 P.
40	Anticlines and Syncline. .	„ „ „ 15 P.
785	Contortion.	Purbeck rocks, Stair Cove, Lulworth. 3 P.
824	„	„ „ „ „ 3 S.
582	„	„ „ „ near view. 6 S.
578	„	Carboniferous rocks, Hartland. 6 S.
435	„	Ordovician rocks, Hope, Salop. 1 P. S.
144	Contortion.	Elland flagstones, Armley, Yorkshire. 45 P.
1692	Overfolding.	Ancient Quartzite, Minaun Head, Achill. 9 P.*
1576	„	Ordovician rocks, Portraine, Dublin. 11 P. S.
1728	Fold with middle limb pinched out.	Mulroy Bay, Donegal. 9 P.

Faulting.

1616	Trough fault.	Coal-measures with coal-seam near Kimberley, Notts. 2 P.
1361	Fault.	Gannister, Rowley's Quarry, Leeds. 3 P.

Brecciation.

203	'Breccia-gash,' Magnesian Limestone.	Marsden, Durham. 16 P.*
1208	'Crush conglomerate.' . .	Isle of Man. 1 P.

Jointing.

66	Flagstones, worn into cave and arch.	Old Red Sandstone, Holburn Head, Caithness. 17 P.*
1078	Devonian rocks. . . .	Castle Rock, Lynton, Devon. 3 S.
101	Carboniferous Limestone, 'Grikes.'	Near Grange, Lancashire. 3 P. S.
102	„ „	„ „ 3 P. S.
1504	„ „	Hunt Pot, Ribblesdale. 18 S.

In the last three cases the joints are weathering into caves.

Unconformity.

424	Raised beach on Devonian rocks.	Hope's Nose, Devon. 13 P.
80	Llandovery on Arenig rocks. .	Hope Dingle, Salop. 1 P. S.
180	Carboniferous on ancient rocks.	Thornton Force, Ingleton. 3 P. S.
1629	Magnesian Limestone on Millstone grit.	Knaresborough. 3 P.
1276	Trias resting on pre-Cambrian slates.	Woodhouse Eaves, Charnwood Forest. 1 P. S.
1581	Carboniferous Limestone on Ordovician rocks.	Moughton, near Settle. 11 P. S.
1697	Lias on Carboniferous Limestone.	Southerdown, Glamorgan. 43 P.
1596	Cretaceous conglomerate on Trias.	Murlough Bay, Antrim. 9 P.*

Surface Agencies; Denudation and Deposit.

Running Water; streams.

839	Storm Gorge.	Langtoft, near Driffield. 19 P.
963	Pot-hole in stream. . .	Glenariff, Antrim. 9 P. S.*
434	„ „	Rumbling Bridge, Dunkeld. 13 P.
57	Waterfall.	Pistyll Rhaiadr, Montgomeryshire. 20 P.
1084	„	Rocky Valley, Tintagel. 3 S.
1569	„ over Yoredale Rocks.	Hardraw Scar, Hawes, Yorkshire. 3 P.

Caverns.

Regd. No.			
99	Weathered joints in Carboniferous Limestone.	Near Grange, Lancashire.	3 P. S.
353	Caves.	Cae Gwyn, Vale of Clwyd.	4 P.
1502	Interior of Brow Gill Cave.	Ribblesdale.	18 S.
1509	Stalactites.	Gaping Gill, Ingleborough.	18 S.
1510	,,	,, ,,	18 S.
230	Pipe in Chalk.	Under Thanet Beds, Elham Valley Railway.	21 P.
1544	Icicles, showing line of springs.	Severn Tunnel, Monmouth.	41 P.
1612	Gravel, &c., in pocket in Carboniferous Limestone.	Weaver Hills, Staffs.	22 P.

Wind Action.

1320	Stack of Keuper Sandstone cemented by Barytes.	Peakstones Rock, near Alton, Staffs.	22 P.
487	Millstone Grit.	Brimham Rocks, Harrogate.	3 P.
494	,,	,, ,,	3 P.
490	,,	,, ,,	3 S.
507	Tunbridge Wells Sand.	The Toad Rock, Tunbridge Wells.	3 P.
460	Blown sand, stratified.	Leasowe, Cheshire.	10 P.
461	,, ,,	,, ,,	10 P.
1650	Sand-dunes advancing.	Church Tower, Eccles, Norfolk.	44 P.
1699	,, ,,	,, ,, ,,	1 P.
1700	,, ,,	,, ,, ,,	1 P.

Action of Rain.

753	Alltdearg Burn, Fochabers, Elgin.	Earth pillars in Old Red Sandstone conglomerate.	46 P.
754	,, ,,	,, ,,	46 P.
755	,, ,,	,, ,,	46 P. S.
756	,, ,,	,, ,,	46 P. S.
757	,, ,,	,, ,,	46 P.
758	,, ,,	,, ,,	46 P.
760	,, ,,	,, ,,	46 P.

Frost and Weathering.

727	Screes of felsite.	Head of Glencorse, Edinburgh.	23 P.
	,, ,,	,, ,, ,,	23 P.
735	Fallen blocks on mountain side.	Tyn-y-wern, Montgomery.	20 P.
251	Denudation of granite.	Happy Valley, Mourne Mountains.	9 P.*

Glaciation; Glaciated Surfaces.

404	Scratched surface.	Loch Doon, Ayrshire.	24 P.*
325	,, ,,	Trefriew, Carnarvon.	7 P.
323	Roche moutonnée.	Capel Curig, Carnarvon.	7 S.
322	Roches moutonnées.	,, ,, ,,	7 P.
1190	Glaciated rocks.	Cwm Glas, Snowdon.	25 P. S.
714	Roche moutonnée.	Arthur's Seat, Edinburgh.	23 P.
718	Undercutting by glaciation.	Blackford Hills, Edinburgh.	23 P.
321	Perched blocks on smoothed surfaces.	Pass of Llanberis.	7 P.
324	Boulder on glaciated surface.	Cwm Tryfaen, Carnarvon.	7 P. S.
1497	Perched block on glaciated surface.	Pass of Llanberis.	3 P.

Glaciation; Erratic and Perched Blocks.

1496	Perched block.	Near Pen-y-Pass, Llanberis, Y Foel Perfedd.	3 P.
320	,, ,,	,, ,, ,,	7 P.
449	,, ,,	,, ,, ,,	1 S.

Regd. No.		
931	Erratic of Mount Sorrel granite.	Aylestone, Leicester. 26, 27 P.*
248	„ „ Mourne granite. .	Cloughmore, Rostrevor, Down. 9 P. S.*
109	„ on Carboniferous Limestone.	Near Grange, Lancashire. 3 P. S.
112	„ „ „	„ „ „ 3 P. S.
120	„ of „	Great Orme's Head. 3 P. S.

Glaciation—Boulder Clays and Contorted Drifts.

802	Glaciated boulder in clay. .	Near Crieff, Perth. 28 P.
1057	Characteristic denudation of boulder clay. . . .	Filey. 3 P.
1345	„ „ „	„ 3 S.
883	Contorted glacial drift. . .	Sherringham, Norfolk. 29 P.
1002	Moraine cut through by river.	Bloody Bridge, Newcastle, Down. 32 P. S.

Marine Action; Denudation.

720	Tunnel eroded by sea. . .	Devil's Cave, Elie, Fife. 23 P.
721	„ „ „ . .	„ „ „ 23 P.
61	Erosion along joints. . .	Bird's Island, Caithness. 17 P.*
647	Arch of erosion. . . .	Carsaig Arches, Mull. 17 P.*
1351	Sea-cirques.	Filey, Yorkshire. 3 P.
1334	Caves.	Flamborough. 3 P.
1337	Stacks.	„ 3 P.
1136	Far advanced marine work on chalk.	„ 3 P.
1134	Marine action. . . .	Thornwick Bay, Flamborough. 3 S.
573	Sea stacks.	Boscastle, Devon. 6 S.
541*a*	Sixty years' denudation. .	Marino, Holywood, Down. 32 P. S.

Marine Action; Landslips.

414a	Cliff falls. . . .	Shakespeare Cliff, Dover (before great fall, 1897). 30 P.
1635	„	Shakespeare Cliff, Dover (after great fall). 30 P.
799	Groin bent by landslip in 1893.	Sandgate. 30 P.
868	Wrecked house. . . .	„ 30 P.
869	Floor of house fractured. .	„ 30 P.
1342	Speeton Clay slipping. . .	Speeton, Yorkshire. 3 P.

Volcanic and Plutonic Rocks.

Rock Types and Relations.

1288	Agglomerate.	Charnwood, Leicester. 1 P. S.
713	„	South side Arthur's Seat, Edinburgh. 23 P.
723	Tuffs, weathered. . . .	Burntisland, Fife. 23 P.
241	Lava sheets and ash beds, &c.	Pleaskin Head, Antrim. 9 P.*
662	„ „ „ .	Down Hill, Londonderry. 32 P.
719	Brecciated Lava . . .	East of Kinghorn, Fife. 23 P.
973	Basalt dyke, through chalk. .	Cave Hill, Belfast. 9 P. S.*
1262	Granite dyke.	Brazil Wood, Charnwood. 1 P S.
603a	Veins of granite in slate. .	Foel Tan-y-Grisiau, Merioneth. 31 P.
534	Two intersecting dykes of basalt in Trias.	Macedon Point, Down. 32 P. S.
533	North Star dyke. . . .	Ballycastle, Antrim. 32 P.
675	Dyke and branching sill of basalt.	Scrabo Hill, Down. 32 P.
677	Branching sill of basalt in Trias.	Scrabo Hill, Down. 32 P.
970	Intrusive sills of basalt. . .	Whitewell, Belfast. 9 P.*
1198	Dolerite sill in Tremadoc rocks.	Criccieth, Carnarvon. 25 P. S.
715	Dolerite sill.	Salisbury Craigs, Edinburgh. 23 P.

Regd. No.		
722	Dolerite sill, including shale .	Salisbury Craigs, Edinburgh. 23 P.
245	Laccolite of dolerite. . .	Fair Head, Antrim. 9 P. S.*
89	„ base of, resting on shales.	Corndon, Montgomery. 1 P.
88	„ . „ „	„ „ 1 P.
90	Laccolite, summit of, with shales resting on it and a small easement dyke.	„ „ 1 P.
980	Volcanic 'neck.' . . .	Tieveragh Hill, Cushendall. 9 P.*
716	Intrusive felsite. . . .	Glencorse, Edinburgh. 23 P.
*	„ „ . . .	„ „ 23 P.
999	Granite cutting off Ordovician Rocks which are penetrated by a dyke of dolerite.	Glen River, Down. 32 P.
1601	Dolerite dyke cutting through chalk and including patches of it.	Squire's Hill, Antrim. 33 P.
1752	Composite dyke. . . .	Glasdrumman, Newcastle, Down. 9 P.*
1753	„ „ . . .	„ „ „ 9 P.*
1754	„ „ . . .	„ „ „ 9 P.*

Rock-structures.

240	Columnar structure. . .	Giant's Causeway. 9 P.*
236	„ „	„ „ 'Giant's Fan.' 9 P.*
237	„ „	„ „ 'The Honeycomb.' 9 S.*
239	Cup and ball structure. . .	„ „ 'Giant's Gateway.' 9 P.*
849	Columnar diorite in Cambrian.	Atherstone. 7 P.
441	„ diabase. . .	Welshpool. 1 P.
1597	„ rhyolite. . .	Tardree, Antrim. 33 P.
1396	Radiating columns. . .	The Spindle Rock, St. Andrews. 3 S.
1307	Nodular porphyroid. . .	High Sharpley, Charnwood. 1 P. S.
1759	Perlitic structure. . . .	Mexico. 1 P.
1187	Spheroidal structure. . .	Ballengeich, Stirling. 34 P.

Origin of Surface Features.

Valleys.

978	Denudation of Tertiary Basalt, &c.	Glenariff, Antrim. 9 P.*
1147	Denudation of Carboniferous Limestone.	Trow Gill, Clapham. 3 P.

Escarpments.

1319	Aymestry Limestone. . .	Weo (View) Edge, Salop. 29 P.
1435	Millstone Grit. . .	The Roaches, Staffs. 22 P. S.
1432	„ „	„ „ „ 22 P.
1315	Carboniferous and igneous rocks on Cambrian and Uriconian Rocks.	Wrekin, Salop. 29 P.
1421	Rhætic and Lower Lias. .	Sedgemoor and Polden Hills, Somerset. 22 S.

Influence of structure planes.

1085	Joints governing denudation.	Tintagel. 3 P.
1561	„ „ „	Hilbre Island, Cheshire. 10 P.
1191	„ „ „ and forming caves.	Criccieth. 25 P. S.
1232	Bedding and joints influencing formation of caves.	Criccieth. 25 P. S.
1122	„ „ „	Filey. 3 P.
1585	Dip influencing valley contours.	Cheddar, Somerset. 11 P.

Ancient Surface Features.

Perched Boulders.

Regd. No.			
1381	Boulder resting on denuded limestone pedestal.	Norber.	3 P.
1382	" " "	"	3 P. S.

Drift-filled Valleys.

1340	In chalk now being re-excavated by the sea.	Flamborough.	3 P. S.
1762	In 'Skiddaw Slate' being re-excavated by stream of Glen Wyllin.	Isle of Man.	1 P. S.

Trias-filled Valleys.

1270	In slates.	Swithland Wood, Charnwood.	1 P. S.
1271	"	" " "	1 P. S.
1292	In Bardon Rock, along old crush-planes.	Bardon, Charnwood.	1 P. S.

Dry Valleys and Caverns.

1368	In Mountain Limestone. . .	Malham and Gordale.	3 P. S.
1373	" "	" "	3 P. S.
1370	" "	Dry Waterfall "	3 P. S.
859	" "	Cheddar Gorge.	2 P.

Buried Cliffs and Taluses.

1460	Pre-Glacial	Sewerby Cliff, Bridlington Quay.	35, 36 P.
972	Chalk cliff and scree covered by Tertiary Basalts.	Cave Hill, Belfast.	9 P.*

Characteristic Rocks and Landscapes.

Pre-Palæozoic.

73	Archæan Gneisses, &c. . .	Whitenhead, Sutherland.	17 P.*
74	" "	" "	17 P.*
1274	Pre-Cambrian 'Slate-agglomerate.'	Bradgate Park, Charnwood.	1 P. S.
981	Ancient rocks covered by Tertiary Basalts.	Murlough Bay, Antrim.	9 S.*

Palæozoic.

1645	Cambrian slates, &c. . . .	Howth, Dublin.	37 P.
603	Tremadoc Slates intruded upon by granitite.	Foel Tan-y-Grisiau, Merioneth.	31 P.
436	Wenlock Limestone. . . .	Wenlock Edge, Salop.	1 P. S.
726	Old Red Sandstone lavas and tuffs.	Pentland Hills.	23 P.
801	Tilted Old Red Sandstone. . .	Crieff and Comrie Railway.	28 P.
474	Carboniferous Limestone. . .	Dovedale, Derbyshire.	3 P.
864	" "	Dinder Wood, Mendip Hills.	2 S.
1422	" "	Cheddar, Somerset.	22 P.
1423	" "	" "	22 S.
135	" "	Great Orme's Head, Llandudno.	3 P. S.
512	" " brecciated.	Near Gargrave.	5 P.
580	" " and Volcanic Rocks.	Brent Tor, Devon.	6 S.
1113	Yoredale Beds.	Bolton Abbey, Yorkshire.	3 P.
405	Ballagan Beds.	Strathblane, Stirling.	24 P.*
717	Carboniferous Volcanic Rocks. .	West of Elie, Fife.	23 P.

Regd. No.		
725	Carboniferous Trachyte. . .	Bass Rock, Haddington. 23 P.
711	,, Lavas and tuffs. .	Burntisland, Fife. 23 P.
159	Magnesian Limestone. . .	Garforth. 5 P.
160	,, ,, ...	,, 5 P.
161	,, ,, ...	S. Milford. 5 P.
162	,, ,, ...	,, 5 P.
164	,, ,, ...	Garforth. 5 P.

Mesozoic.

865	Dolomitic Conglomerate. . .	Croscombe Hills, Somerset. 2 P.
544	Rock-salt in Trias. . . .	Witton Hall, Cheshire. 38,* 1 P.
1322	Keuper conglomerate. . .	Peakstones Rock, Staffs. 22 P.
641	Rhætic Beds.	Lavernock. 7 P.
1354	Corallian Rocks on Oxford Clay.	Gristhorpe Cliff, Yorkshire. 3 P.
1119	,, ,, ...	Filey Brigg, Yorkshire. 3 S.
1415	Portland Stone and Cherts. .	Tilly Whim, Swanage. 39 P.
581	Contorted Purbeck Rocks. . .	Stair Cove, Lulworth. 6 S.
1552	Wealden Strata. . . .	Brightstone, Isle of Wight. 40 P.
1533	Lower Greensand Cherts. . .	Leith Hill, Surrey. 1 P. S.
795	Upper Chalk.	St. Margaret's Bay, Kent. 30 P.
1331	Chalk and Boulder Clay. . .	Flamborough. 3 P.
1153	Chalk cliff.	The 'Giant's Head,' Portrush. 3 P.
1599	Tabular flints, faults, and dykes in chalk.	Squire's Hill, Belfast. 33 P. S.

Cainozoic.

225	Thanet Beds on Chalk. . .	Elham Valley, Kent. 21 P.
1719	Bed of flints on Chalk altered by Basalt sheets.	Cave Hill, Belfast. 9 S.*
884	Norwich Crag on Chalk. . .	Thorpe, near Norwich. 29 P.
1344	Boulder Clay on Corallian Rocks.	Filey, Yorkshire. 3 P.
1324	Implementiferous Gravel. . .	Near Farnham, Surrey. 39 P.
51	Ossiferous Cavern. . . .	Knockmore, Fermanagh. 9 P.*
463	Submerged Forest. . . .	Leasowe Shore, Cheshire. 10 P.
1755	Kitchen Midden. *Purpura lapillus.*	Roundstone, Galway. 9 P.*
1756	,, ,, *Littorina.*	Roundstone, Galway. 9 P*.
1757	,, ,, *Patella vulgata.*	Roundstone, Galway. 9 P.*

Names and Addresses of Donors and Photographers.

	P.	S.
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LIST 5.

Reference List of Photographs illustrating Geological Papers and Memoirs.

Geologists' Association. 'Proceedings.' Vol. XIII. (1893–94), *figs.* 2, 5 *and* 6. *Report of Excursion to Norwich, &c. By* C. Reid *and others. From negatives by A. Strahan.*

Regd. No.		
1711	Western Chalk Bluff, Trimingham.	Contorted Chalk under Drift.
1712	Cliff at Runton.	Contorted Drift with Chalk.
1713	Cliff at Beeston.	'Augen' structure in contorted Drift.

Vol. XIV. (1895–96), *p.* 310. *Plate XI., A and B. Excursion to Swanage, &c. By* H. W. Monckton *and others. From negatives by* H. W. Monckton.

1415	Tilly Whim 'Caves,' Swanage.	Portland Stone and Chert Beds.
1418	Durlston Head.	Base of Purbeck Beds resting on Portland Stone.

Geological Magazine. Dec. IV., Vol. III., 1896, *page* 18. *Paper on Perlitic Structure. By* W. W. Watts. *From negative by* W. W. Watts.

1759 Perlitic structure in obsidian. Mexico.

Dec. IV., Vol. IV. (1897), *page* 31, *&c. Plates II., III., IV. Paper on British Geological Photographs. By* W. W. WATTS. *From negatives by* Miss ANDREWS, G. BINGLEY, *and* E. J. GARWOOD.

Regd. No.		
541*a*	Pump at Marino, Down.	Encroachment by Sea.
1340	Flamborough Head.	Drift-filled Valley in Chalk.
890, 891	Cullernose, Northumberland.	Intrusive character of Whin Sill.

Ancient Volcanoes of Great Britain. By Sir A. GEIKIE, 1897. *Vol. II., Figs.* 316, 331, 333. *From Negatives by* R. WELCH *and* G. P. ABRAHAM.

245	Fair Head, Antrim . . .	Intrusive mass of Columnar Dolerite.
1701	Sgurr na Gillean, Skye . .	Gabbro.
1702	The Gendarme, Sgurr na Gillean	Gabbro and Dykes of Dolerite.

The Practical Photographer, Vol. VIII., 1897. *No.* 88, *pp.* 113–115. *Paper on 'Geological Photographs and Photographic Surveys.' From negatives by* G. BINGLEY *and* A. STRAHAN.

1629	Knaresborough	Magnesian Limestone on Millstone Grit.
1381	Norber	Perched Boulder.
1135	Thornwick Bay, Flamborough .	Chalk and Boulder Clay.
1528	Near Lulworth	Purbeck Beds.

Journal Scottish Mountaineering Club. From negative by W. LAMOND HOWIE.

1761 Ben Nevis from Carn Mor Dearg.

Open-air Studies. By Prof. G. A. J. COLE. 1895. *From negatives by the late* J. J. COLE.

582	Stair Cove, Lulworth. . .	Contorted Purbeck Rocks. Pl. XI.
588	Cwm Glas Moraine, Carnarvonshire.	*Frontispiece.*

From negatives by R. WELCH.

1724	Sands and Gravels, Moylena, Antrim.	Pl. III.
982	Murlough Bay, Antrim. . .	Pl. IV.
236	The Giant's Fan, Antrim. . .	Pl. VI.
973	Cave Hill, Belfast. . . .	Dyke in Chalk. Pl. VII.
251	Slieve Bingian, Down. . .	Granite. Pl. IX.
963	Glenariff, Antrim. . . .	Pot-hole in stream. Fig. 1.
1751	Castles of Kivvitar, Mourne Mountains.	Granite. Fig. 16.

Irish Naturalist. From negatives by Miss M. K. ANDREWS.

541*a*	Old pump, Cultra. . . .	Vol. ii. 1893. Pl. I.
534	Dykes, Macedon Point. . .	Vol. iii. 1894. Pl. IV. figs. 1 and 2.
553	North Star Dyke, Ballycastle. .	

From negatives by R. WELCH.

1726	Contorted Quartzite, Rosapenna, Donegal.	Vol. iii. 1894. Pl. V.
1679	Derryclare Lake and Mountain, Connemara.	Vol. iv. 1895. Pl. IV.

Cretaceous Fossils in Aberdeenshire.—Report of the Committee, consisting of T. F. JAMIESON (*Chairman*), A. J. JUKES BROWNE, *and* JOHN MILNE (*Secretary*), *appointed to ascertain the Age and Relation of the Rocks in which Secondary Fossils have been found near Moreseat, Aberdeenshire.*

APPENDIX.—*On the Fossils collected at Moreseat, by* A. J. JUKES BROWNE, *page* 337

MORESEAT is in the parish of Cruden, in the east of Aberdeenshire. It lies at an elevation of 300 feet above sea-level, and the surface of the ground slopes to the sea at Cruden Bay, distant five miles to the south. On the north the ground rises gradually, reaching the height of 450 feet above sea in Torhendry Ridge, which is strewn with chalk-flints in great abundance.

Previous Investigations.—Geologists are indebted to Dr. William Ferguson of Kinmundy for the earliest notices of Greensand at Moreseat. In 1839 an excavation 9 feet deep was made for the water-wheel of a mill, and a drain away from it, on the south side of the farm steading, a little below the 300-feet level. The excavation was made in clay, and in it were found layers of sandstone containing many fossils. The Rev. J. Johnstone, Belhelvie, who lived at Moreseat at the time, says that the discovery excited great interest, and that Moreseat was visited by scientific men, amongst others by Professor Knight of Marischal College and University, Aberdeen, who communicated with Dr. Thomson of Glasgow University on the subject, and informed his class of 1839–40 that Greensand had been discovered at Moreseat. Dr. Ferguson was a student in this class, and thus had his attention directed to the Moreseat fossils from the first. Hundreds of loads of clay were removed from the excavation, and many fossils were collected; but when the wheel was put in and built up, and the drain was covered up, there remained no trace of the interesting discovery.

In 1849, on making a deep ditch alongside a road to the north of the farm steading, and a little above the 300-feet level, the same clay, sandstone, and fossils were met with. Dr. Ferguson sent a notice to the Philosophical Society of Glasgow.[1] Next year he visited the newly-made ditch, and sent an account of the original discovery and a description of what he saw to the 'Philosophical Magazine.'[2] Dr. Ferguson's description of what he saw is quoted here, because it exactly coincides with what was seen in subsequent excavations. 'An excavation about 7 feet in depth was made, and the section presented irregular layers of unctuous clay, of a dark brown colour and soapy feel, and so tough and adhesive as to render it a work of considerable labour to dig it out. Interstratified with this clay were thin layers of a compact sandstone. These layers of sandstone were not continuous; they graduated into each other, thinned out, disappeared, and reappeared most confusedly. They were very much inclined, dipping towards the south. The whole mass had much the appearance of having been drifted; although from the nature of the matrix, and the state of preservation in which the shells were found, it did not appear as if it could have been drifted far. The sandstone was tough and soft when

[1] See Proceedings of the Society, vol. iii. 1849. [2] See vol. xxxvii. 1850.

newly dug, but hardened on exposure to the air and became light-coloured in drying. When wet, it presented a mottled appearance, the colour being greenish; when dry, this almost disappeared.'

In 1856 a collection of fossils from Moreseat, made by Dr. Ferguson, was examined by Mr. J. W. Salter, of the Museum of Practical Geology, Jermyn Street, London, and Mr. W. H. Baily; and a list of twenty specimens named by them was presented to the Geological Society of London, and published next year in the Quarterly Journal of the Society, along with a note by Dr. Ferguson. Types of these fossils are preserved in the Museum. Mr. Salter regarded the Moreseat fossils as an indication, in the near neighbourhood, of Upper Greensand *in situ*.

In the memoir descriptive of the sheet of the Geological Survey containing Moreseat, notice is taken of the Greensand fossils found there, and of the Chalk-flint fossils found at Bogingarrie, a few miles to the south-west, also described by Mr. Salter; but the surveyor does not say that he saw at Moreseat any fossils or fragments of Greensand sandstone.

In 1894 the Secretary of the Committee was lecturing at Cruden on Geology and Agriculture for Aberdeen County Council, and was induced by the mention of Greensand in the memoir to visit Moreseat and make inquiries; but he could learn nothing further than that fossils had been found in the excavation made for the mill-wheel, and as it was enclosed with masonry nothing could be seen. He visited the place repeatedly and examined all the ditches and watercourses on the farm, but found no fossils.

The reason of this was seen afterwards. When pieces of the sandstone were exposed to frost they became a soft paste on thawing, and all trace of the fossils they contained disappeared. He afterwards met with Mr. Alexander Insch, Peterhead, who has made a collection of Chalk-flint fossils found on the ridge running south-west from Buchanness, and who had heard that fossils had been found north of the farm steading. Accompanied by him and Mr. D. J. Mitchell, Blackhills, Peterhead, he again visited Moreseat. An excavation was made to the north of the ditch seen by Dr. Ferguson, and after passing through a foot or eighteen inches of sandy clay, thin layers of sandstone with fossils were found. The appearance of the layers of sandstone was peculiar. They conveyed the idea that they were cakes of some plastic material spread out in a soft state, yet not wet enough to bear great lateral extension without cracking. The layers were full of vertical cracks, which broke them up into small fragments. These might have been caused by shrinking on drying, as the excavation was made where the ground would be dry in summer. The method of occurrence was the same as that described by Dr. Ferguson already quoted. The fossils found were chiefly shells and spines.

Specimens were forwarded to the British Association with an application for a grant of money to ascertain by deeper excavation whether the bed from which the sandstone had come could be found there. Though the application was unsuccessful, digging was continued by Messrs. Mitchell and Insch, who collected a large quantity of fossils in various places, over an area a quarter of a mile broad, in the neighbourhood of Moreseat.

In 1895 specimens were sent to Dr. H. Woodward, of the Natural History Museum, London, with another application for a grant from the British Association. A grant of 10*l.* was given, and the Committee already named was appointed.

Dr. J. W. Judd, of the Royal College of Science, South Kensington,

was consulted about the specimens already collected by Messrs. Mitchell and Insch, and by his advice they were sent to the Geological Survey Office, where they were examined and compared with Dr. Ferguson's typical specimens by Mr. G. Sharman and Mr. E. T. Newton. They published a statement of the result of their examination in the 'Geological Magazine' in June 1896. They came to the conclusion that the specimens had 'been derived from beds where a large part of the Cretaceous series of strata occurs; not only Upper and Lower Chalk, and Upper Greensand as pointed out by Salter, but also beds of Lower Greensand or Speeton Clay age.' In making this statement they seem to have referred not only to the specimens collected by Messrs. Mitchell and Insch, but also to the Chalk-flint specimens in the Ferguson collection. It may therefore be noted that though flints are found in great abundance on the ridge above Moreseat, they become fewer in going down the hill-side, and are comparatively scarce at Moreseat, and it may be assumed that none of the flint-fossils in the Ferguson collection were found in the immediate neighbourhood of the Greensand fossils.

Work of the Committee.—On being made aware of their appointment the Chairman and the Secretary met on the ground, accompanied by Messrs. Mitchell and Insch; Dr. Ferguson unfortunately was unable to be present. Mr. Johnstone, the proprietor of the farm, kindly consented to allow an excavation to be made. All the places where fossils had been found were examined, and it was resolved to sink a shaft at the highest place where they were certainly known to be, in the belief that the fragments of sandstone had been moved from a higher to a lower level. The place selected is on a knoll north of Moreseat, about 330 feet above the sea-level, and about a quarter of a mile from the place where fossils were found in 1839. The ground to the north is covered with peat-moss overgrown with heather, and nothing can be seen of its character. Half a mile to the north-east there is some cultivated land, and a pit had been sunk by a crofter for a pump in white unstratified siliceous matter, apparently detritus of chalk-flints. To the north-west another pit had been dug. At first glacial drift clay was met with, then fine stratified sand, unsuitable for a pump-well, and the excavation was stopped at 14 feet deep. This hole was 50 feet above the site selected for the shaft. It was thought best to defer the sinking of the shaft till the following summer to avoid risk of obstruction from water.

Mr. J. T. Tocher, the Secretary of the Buchan Field Club, which is affiliated to the British Association, undertook to contract for the work, and along with Mr. Mitchell to visit it while in progress, and to examine the material excavated.

The shaft was dug in the summer of 1896, and a depth of 30 feet was attained. The first foot consisted of ordinary soil. Below it was found a yellowish-brown sandy clay mixed with small fragments of sandstone and pebbles of quartzite and flint. The sandstone was afterwards found to be composed of Quartz, Mica, Glauconite,[1] and Colloid Silica, and it may be termed Glauconitic Sandstone. Almost every fragment yielded fossils, mostly small shells. At 3 feet the clay became finer and the sandstone fragments more abundant. At 4 feet they were in layers among the clay, gradually thinning out and disappearing, as described by Dr. Ferguson. At 5 feet, on the south side of the shaft, a deposit of fine

[1] 'Glauconite. Round grains; dull resinous; light green; chemical composition, silicate of protoxide of iron and potash.'—Heddle, in *Encyc. Brit.*, vol. xvi. p. 415.

white sand was found, in which were pebbles of granite, quartzite, and flint. In the other part of the shaft the clay continued, with numerous bits of the grey glauconitic sandstone in a layer, much broken, dipping to the south, which is the direction of the slope of the surface of the ground at Moreseat. The mass of sand increased down to 8 feet, where it ended. At the bottom of the sand there was a block of granite a foot in diameter, and under it a large flint pebble. At 10 feet there was, on one side, a mass of black clay with a soapy feel, in which sandstone fragments, much worn, were found. This black clay stopped at 11 feet. At 14 feet it began to appear again, and to take the place of the yellowish-brown clay, which ended at 16 feet. The lower part of it contained many stones. From this level the black clay continued all the way down to 30 feet, where it was succeeded by red laminated clay, without stones of any kind. The black clay contained large stones of granite and quartzite and small fragments of the glauconitic sandstone all the way, but the stones grew fewer in number the deeper the shaft was sunk, and the sandstone fragments had almost ceased at 27 feet. The excavation could not be carried farther than 30 feet, because, on reaching the red laminated clay, water began to come in, and the funds were exhausted.

The Committee regret that they were unable to ascertain the nature of the solid rock under the shaft. Most likely it would have been found to be granite, the rock seen at the sea-coast from Cruden Bay to Peterhead. The shaft was evidently in glacial drift clay all the way, and therefore the sandstone fragments were not *in situ*, but had been transported, apparently from the north. By a series of pits a few feet deep made in this direction it might be possible to follow the sandstone fragments farther up the hill, and a shaft sunk at the uppermost place where they could be found might discover the bed from which they came; yet the Committee cannot venture to express a confident opinion that another excavation would be more successful than the last in finding the origin of the Glauconitic Sandstone. Many appearances indicate that the latest changes on the surface of the ground in the district in which Moreseat is situated were caused by local glacial sheets, perhaps not on a great scale, yet capable of moving great quantities of loose and soft matter. The white sand in the shaft seemed to have been moved bodily from a bed seen to the north-west at a higher level. The original seat of the Glauconitic Sandstone may have been to the north of the shaft, a little farther up the hill, and yet the bed may have been entirely removed by ice descending the hill. If, however, the British Association renew the grant, the Committee will be happy to make another attempt to find the origin of the Moreseat fossils. Some of the gentlemen who have aided in the work might be added to the Committee.

Mr. Tocher, F.I.C., analysed the clays found in the shaft, and ascertained that the reddish colour of the one was due to ferric iron, and the black colour of the other to ferrous iron. There is at Aldie, about a mile from Moreseat, a band of very black igneous rock. There may be also some of it above Moreseat, concealed by superficial drifts, and if so it would account for the colour of the black clay.

Mr. Insch collected a large quantity of sandstone fragments containing fossils. These were examined by Mr. A. J. Jukes Browne, and will ultimately be deposited in a museum in Aberdeen for preservation. Mr. Jukes Browne is of opinion that the sandstone was a deposit made in clear water of a moderate depth, not far from land, and that the fossils in

it show that it corresponds to the Lower Greensand of the Isle of Wight. Mr. Jukes Browne's report is appended in full.

APPENDIX.

Report on a Collection of Fossils from Moreseat, Aberdeen.

By A. J. JUKES BROWNE, *B.A., F.G.S.*

The existence of Cretaceous fossils, embedded in a kind of 'Greensand,' and found at Moreseat, near Aberdeen, has been known to geologists for nearly fifty years. Mr. W. Ferguson discussed them in a paper read before the Philosophical Society of Glasgow in 1849, and subsequently communicated to the 'Philosophical Magazine.'[1] In this he observes that most of the remains are casts, and he mentions the occurrence of several species of *Ammonites* and *Belemnites*, as also of *Cardium*, *Terebratula*, *Trochus*, *Solarium*, *Cerithium*, and *Spatangus*.

Some of Mr. Ferguson's fossils were examined and named by Mr. J. W. Salter in 1857,[2] who gave a list of fourteen species, two of them being Ammonites doubtfully referred to—*Am. Selliguinus*, Brong., and *Am. Pailletianus*, d'Orb. Four of the others he describes as new species, and from the remaining six he comes to the conclusion that the fauna is of Upper Greensand age.

From 1857 to 1896 no further light was thrown on the subject, but in the latter year some of the fossils collected by Messrs. Mitchell and Insch were submitted to Messrs. Sharman and Newton, who made a careful examination of them, and communicated the results to the 'Geological Magazine.'[3] They compared these fossils with the specimens described by Salter, which are preserved in the Museum of Practical Geology, and found the matrix to be the same. They also state that though slight differences are noticeable in different pieces of the rock, yet all the samples are 'so similar that one can scarcely question their having been originally derived from the same bed.'

They found, however, that many of the fossils could not be identified with any Upper Greensand species, but were Lower Cretaceous forms, many of them identical with those occurring in the Speeton Clay. They admitted, however, a few species which occur in the Upper Cretaceous series only, and have not been found in any British Lower Cretaceous deposit. Hence they conclude 'that the faunas which in the south mark the distinct horizons of Lower Greensand, Gault, and Upper Greensand are here in Aberdeenshire included in one bed of nearly uniform character throughout.' This conclusion certainly invested the Moreseat fossils with still greater interest than they possessed before.

A collection of the fossils was sent to me by the Rev. John Milne in September 1896, but it was impossible for me to examine them in time to report on them before the meeting of the British Association in that year. I have since, however, given them careful attention, and have received much assistance from Messrs. Sharman and Newton, whose previous acquaintance with many of the species has saved me much time and labour.

It is not an easy task to identify these Moreseat fossils, for they are

[1] *Phil. Mag.*, vol. xxxviii. p. 430 (1850).
[2] *Quart. Journ. Geol. Soc.*, vol. xiii. p. 83.
[3] *Geol. Mag.*, Dec. 4, vol. iii. p. 247.

all in the state of casts and impressions. In no case does any actual shell or test remain, but the firmness of the rock has in most cases prevented the enveloping matrix from being pressed down on to the internal cast, so that the external cover generally retains the shape and impression of the original shell, and a mould can, if necessary, be taken from it. The fossils had been carefully collected, and as both casts and covers had been transmitted, it has been possible to determine many of the species.

Before discussing the species, however, the rock itself merits description, for its peculiar characters seem to have escaped previous observers. To the eye it presents itself as a very fine-grained siliceous rock, resembling malmstone, dark grey when damp and freshly broken, drying to a lighter grey. Fractured surfaces often show spots and patches of darker material than the rest of the mass. Under the lens it showed a finely-granular matrix, containing many small grains of glauconite, and numerous flakes of mica, with small patches of a yellowish-green mineral which is apparently a decomposition product.

The general aspect and light specific gravity of the rock led me to suspect the presence of colloid silica, and accordingly I sent specimens to Mr. W. Hill, F.G.S., for microscopical examination. Mr. Hill cut slices from two of these, and furnishes me with the following account of the structure exhibited by them :—'The material of both slides is alike, and compares most nearly with the micaceous sandstone of Devizes (Upper Greensand). The ground mass consists of amorphous and semi-granular silica, neutral to polarised light, with little or no calcite. There are many sponge spicules, the walls of which have mostly disappeared, but which are outlined in the matrix. The space once occupied by the spicule is often partly filled with globules of colloid silica, like those described by Dr. Hinde in malmstone, and similar globules are dispersed through the mass of the rock. There is much quartz sand in small, angular, even-sized grains, but not so much as in Devizes sandstone. Glauconite grains are also abundant, but the quantity varies much in different parts of the rock ; the grains seem to be breaking up, and are often seamed with vein-like markings. There are also larger patches of dirty-green material, which has a somewhat indefinite outline, and may be of secondary formation. Small flakes of mica are scattered through the slides, but it is only when these are cut transversely that the mineral can be easily identified.'

From the above description it will be seen that the rock may be termed a *gaize*—that is, a fine-grained sandstone, in which colloid silica is an important ingredient ; this is not a common rock, and in England it is only known as occurring in the Upper Greensand in association with malmstone. In France a gaize of Lower Gault age, containing *Ammonites mammillatus* and *Am. interruptus*, occurs in the Ardennes (Draize), but I can find no record of the rock occurring in the Lower Cretaceous series either in France or Germany.

The formation of gaize and malmstone probably took place in clear water of a moderate depth ; it is not a shallow water deposit, and yet it was deposited within the range of a current which carried fine sand. The abundance of sponge spicules shows that the conditions were such as to favour the growth of siliceous sponges.

Remarks on some of the Fossils.

The collection sent to me includes some species which have not yet been recorded from the Moreseat rock, and as these are all Lower

Cretaceous forms, the Vectian element in the fauna is clearly very strong —so strong indeed that I am led to doubt the existence of some of the Upper Cretaceous species which have been supposed to occur. I therefore offer some remarks on certain species, and give a complete revised list of the Moreseat fauna, so far as it is at present known.

Micrabacia coronula, Goldf.—This identification requires confirmation. It depends solely on Salter's authority, for the specimen he saw is not in the Jermyn Street Museum, and no other specimen has been detected in the collections recently made. The species is not known to occur below the Upper Greensand (zone of Pecten asper), and would be difficult to recognise from a cast only.

Echinoconus castanea, Brong.—This also requires confirmation, for the specimen so named by Mr. Salter has not been found at Jermyn Street, and no other example has been seen. In England its earliest appearance is near the top of the Upper Greensand, but in Switzerland it ranges down to the base of the Gault (see de Loriol in Echinologie Helvétique), so that it may in some localities range even lower. No species of Echinoconus, however, has yet been recorded from rocks of Lower Cretaceous age.

Discoidea decorata (?), Desor.—This specimen was among those sent by Mr. Milne. It consists of a nearly perfect external mould in two parts. It differs from *D. subuculus* in having close-set rows of nearly even-sized tubercles; eight rows on the interambulacral areas, four on each set of plates; and four rows on the ambulacral areas, but the two inner rows do not reach either to the apex or to the peristome. The mouth and vent are both rather large. In these respects it agrees with *D. decorata.*

Mr. C. J. A. Meyer having informed me that he possessed specimens of a Discoidea from the Vectian of Hythe, the Moreseat specimen was sent to him for comparison. He reports that it agrees with those from Hythe, but he is doubtful whether they are referable to *D. decorata*, Desor, or *D. macropyga*, Ag. Both are Lower Cretaceous species.

Rhynchonella compressa.—The specimen so named by Salter is at Jermyn Street, and has been examined again by Messrs. Sharman and Newton, with the result that they think it is only a compressed variety of *Rh. sulcata.*

Waldheimia faba, d'Orb. (non Sow.).—This being only a cast and the shell being smooth, one cannot be quite sure of the species, but the shape is well preserved, and I am indebted to Mr. Meyer for pointing out that it has the squareness toward the front which is characteristic of the species in question. This is well shown in the example figured by Davidson ('Cret. Brach.' Vol. iv., Pl. vi., f. 12–14), which came from the Speeton Clay of Knapton in Yorkshire.

Lima semisulcata, Sow.—This species has appeared in previous lists on the authority of Mr. Salter, but the specimen is in the Jermyn Street Museum, and Mr. Newton informs me that it is only an internal cast, and may, with equal probability, be referred to *L. Dupiniana.* As specimens of the latter do occur, and none referable to *L. semisulcata* have since been found, I think this Upper Cretaceous species may be omitted from the list.

Arca securis, d'Orb.—I have ventured to enter the common Arca of the Moreseat sandstone under the name of *securis* instead of under *carinata*, because the specimens I have examined seem to me to come nearer

to *securis*, and Mr. Meyer, to whom a specimen was sent, is of the same opinion. The two species are so closely allied that some palæontologists regard them as identical; but there are slight differences, and Messrs. Sharman and Newton agree with me in considering the Moreseat specimens to be smaller and shallower in the valve than the ordinary *A. carinata* of the Upper Greensand; and in these respects they resemble *A. securis*. In some of them, moreover, the ribs on the posterior area are like those in d'Orbigny's figure of *securis*; so that, if the forms are separable, I think these should be listed as *securis*.

Leda scapha (?), d'Orb.—I have seen two casts which probably belong to this species, though they equally resemble *L. Mariæ* of the Gault, for, as Mr. Gardner has remarked, there is very little difference between these species.

Pectunculus umbonatus, Sow.—This is another of Mr. Salter's identifications, and unfortunately it also is only an internal cast. There are several species of Pectunculus to which such a cast might belong, but the probabilities are against its being *P. umbonatus*. As no other specimen has occurred among the fossils recently collected, it will be best to leave it without a specific name for the present.

Turbo, like *Goupilianus*, d'Orb.—There is one specimen, a portion of the external impression of the shell, showing an ornamentation resembling that of *Turbo Goupilianus*, which is a Cenomanian species. This specimen, however, was sent to Mr. Meyer, who informs me that he has an imperfect specimen from the Vectian of the Isle of Wight which it equally resembles.

Ammonites flexisulcatus (?), d'Orb.—A small Ammonite was found in breaking up a lump of the material sent to me, and was forwarded, with other specimens, to Messrs. Sharman and Newton. They reported that it most resembles *A. flexisulcatus*, though the portion preserved is smooth and without sulcations.

Nautilus sp., Sow.—Among the fossils sent me by Mr. Milne is the cast of a Nautilus, badly preserved, but showing strong transverse rugations or ribs like those of *N. radiatus*, but its condition is such as to prevent any certainty of identification. Mr. A. H. Foord has kindly examined the specimen, but could not venture to name it.

In previous Collections	In Mr. Milne's Collection	Moreseat Fossils	Speeton Clay and Lower Greensand	Lower Gault	Upper Gault and Malmstone Group	Greensand of Pecten Asper Zone
		Actinizoa.				
p.		Coral (like Micrabacia)				
		Echinoderms				
p.		Ananchytes (? Cardiaster)				
p.	m.	Discordea decorata, Desor (?)	*			
p.		Echinocyphus difficilis, Ag.				*
p.	m.	Enallaster scoticus, Salter				
p.		Echinoconus castanea (?), Brong.		*	*	*
		Annelida				
p.		Serpula				
		Polyzoa				
.		Entalophora (?)				

In previous Collections	In Mr. Milne's Collection	Moreseat Fossils	Speeton Clay and Lower Greensand	Lower Gault	Upper Gault and Malmstone Group	Greensand of Pecten Asper Zone
		Brachiopoda				
p.	m.	Rhynchonella sulcata, Park	*	*	*	
p.		Terebratula sp.				
	m.	Terebratella (cast only)				
	m.	Waldheimia faba, d'Orb. (non Sow.) .	*			
p.		„ hippopus var. Tilbyensis. Dav.	*			
		Lamellibranchiata				
	m.	Anatina sp.				
p.	m.	Arca securis, d'Orb. .	*			
p.		„ Raulini (?) d'Orb. .	*	?		
p.	m.	Astarte striato-costata, Forbe	*			
p.	m.	Avicula simulata, Baily				
p.	m.?	Cardium Raulinianum, d'Orb	*	*		
	m.	Cardium sp. (cast only)				
p.		Corbula				
p.	m.	Cyprina Fergusoni, Salter				
p.	m.	Exogyra (small species)				
p.		Gervillia solenoides, Defr.	*	*	*	
p.		„ near to rostrata				
p.		Goniomya				
p.		Inoceramus				
	m.	Leda scapha, d'Orb.	*			
p.		Lima Dupiniana, d'Orb. . . .	*			
	m.	„ longa, (?) Röm.	*			
p.		„ near to abrupta, d'Orb.				
p.	m.	Limopsis texturata, Salter				
p.	m.	Lucina sp.				
	m.	Ostrea frons (?) Park (carinata, Sow.) .	*	*	*	*
p.		Panopea				
p.	m.	Pecten orbicularis, Sow.	*	*	*	*
p.		Pectunculus sp.				
p.	m.	Pinna tetragona, Sow.	*	*	*	
p.	m.	Plicatula placunea, Lam.	*	?		
p.		Spondylus				
	m.	Tellina				
	m.	Thetis (?)				
p.		Trigonia vectiana, Lyc.	*			
	m.	„ sp. nov.				
	m.	Venus Brongniartina (?), Leym. . .	*			
		Gastropoda				
p.		Acteon				
p.	m.	Cerithium aculeatum, Forbes MS. . .	*			
p.	m.	Dentalium cœlulatum, Bailey				
p.		Phasianella (like ervyna, d'Orb.)				
	m.	Solarium sp.				
p.	m.	Trochus pulcherrimus, Forbes . .	*			
p.		„ sp.				
	m.	Turbo (like Goupilianus, d'Orb.) . .	?			
		Cephalopoda				
	m.	Ammonites flexisulcatus (?), d'Orb. .	*			
p.	m.	„ Mortilleti, P. & Lor. . .	*			
p.	m.	„ Speetonensis (var.) . .	*			
p.		„ Selliguinus (?), Brong. .		*		
p.		Belemnites sp.				
p.		Crioceras Duvallii	*			
	m.	Nautilus, like radiatus, Sow.				

It only remains to indicate the conclusion to which the study of the Moreseat fossils has led me.

Of the species enumerated by Mr. Salter in 1857 four have been omitted from the preceding list, being regarded as doubtful identifications which have not been confirmed by subsequent discoveries. Of the three genera of Echinoderms mentioned by him the *Discoidea* was probably the species which resembles *D. decorata*, and the two named respectively *Diadema* and *Ananchytes* may have been Lower Greensand forms for anything that we know to the contrary.

The number of named species available for comparison with other faunas is now 32. Out of this total no fewer than 24 are species of Lower Cretaceous age, and only 6 of these range into the Gault; 5 are species which have not been found elsewhere, 2 are Upper Greensand species, but 1 of these is a doubtful determination, and 1 is an Ammonite, of which the identification is also doubtful. There is therefore an overwhelming proportion of exclusively Lower Cretaceous species, namely, 18 to 2, while out of the 6 Cephalopods 5 are exclusively Lower Cretaceous forms, the only one which is not being the very doubtful *Am. selliguinus*.

The occurrence of one Upper Greensand echinoderm (*Echinocyphus difficilis*), and the possible occurrence of another ranging from Lower Gault to Chalk (*Echinoconus castanea* (?)) is hardly sufficient evidence to warrant the conclusion that a part of the rock-mass was of Upper Greensand age. There is nothing except the possible *Am. selliguinus* that is specially characteristic of the Gault, and the question then arises,—what is the evidential value of the occurrence of *Echinocyphus difficilis*, and possibly also of *Echinoconus castanea*? I think it may be answered in this way: it is more reasonable to suppose that these two species, or forms very closely allied to them, date really from Lower Cretaceous times, than it is to suppose the deposition of exactly the same kind of rock material should have continued at any one place from the time of the Lower Greensand to that of the Upper Greensand. In other words, I believe that the rock-mass from which the Moreseat fossils have been derived was entirely a Lower Cretaceous rock, but high in that series, and corresponding approximately to the Aptien stage of France, and to the Lower Greensand or Vectian of the Isle of Wight.

Singapore Caves.—Interim Report of the Committee, consisting of Sir W. H. Flower (*Chairman*), Mr. H. N. Ridley (*Secretary*), Dr. R. Hanitsch, Mr. Clement Reid, *and* Dr. A. Russel Wallace, *appointed to explore certain caves near Singapore, and to collect their living and extinct Fauna.*

The Committee has received from Mr. Ridley an account of a preliminary examination of the caves of Kwala Sum pur, and also notes on the animals now inhabiting them. At the time of writing Mr. Ridley expected soon to be able to pay another visit, and to use gunpowder to break up the massive stalagmite. A first attempt to explore the cave deposits was not successful, as dynamite was used and proved unsuitable for the purpose. It will perhaps be better to reserve an account of the living cave fauna till fuller collections have been made and the specimens have all been determined. The Committee asks for re-appointment and the renewal of the unexpended balance of the grant.

The Fossil Phyllopoda of the Palæozoic Rocks.—Thirteenth Report of the Committee, consisting of Professor T. WILTSHIRE (*Chairman*), Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*). (*Drawn up by* Professor T. RUPERT JONES.)

CONTENTS.

§ I. 1889–1892. Anomalous Silurian Phyllopods (?) from Germany and America.—In the 'Sitz.-Ber. Gesell. naturf. Freunde zu Berlin,' 1890, p. 28, Dr. A. Krause described a small fossil carapace of doubtful alliance, but possibly related to the Phyllopods, from the North-German gravel of Scandinavian Beyrichia-limestone (Upper Silurian). In the 'Zeitsch. Deutsch. Geol. Gesell.,' vol. xliv. 1892, p. 397, pl. xxii., figs. 19 *a–c*, Dr. A. Krause redescribed and figured this anomalous little fossil.

Its lateral moieties are not free, separate valves, but united by an antero-dorsal suture for a third of its length, and by an antero-ventral suture for half of its length, the posterior region remaining open at the edges. It also shows in front a round aperture, with a sulcus formed by the somewhat inverted edges below it. The test is nearly oval and compressed; thickest and subacute in front; bearing a small, low, subcentral swelling. The surface has some reticulate ornament along the margins for the most part, succeeded by linear, radiating, and concentric sculpture towards the more convex area, which is finely punctate. It is 6 mm. long, 4 mm. high, and 1·5 mm. thick.

In S. A. Miller's 'North-American Geology and Palæontology,' 2nd edition, 1889, p. 549, fig. 1009, an allied form is described and figured as *Faberia anomala*, n. sp. et gen., from the Hudson-River group, Ohio (Lower Silurian). This has evidently some analogy to the foregoing Upper Silurian form. It has a compressed, ovoidal, smooth shell, consisting of two moieties, partially sutured above and below, and is rather smaller than the German specimen.

§ II. 1885–1894. Cambrian Phyllopoda (?).—Dr. G. F. Matthew, of St. John, New Brunswick, has discovered several very small organisms in the Cambrian rocks of North-Eastern America, some of which he regards, with doubt, as having been carapace-valves of Phyllopodous Crustaceans. He has described and figured them in the 'Transactions of the Royal Society of Canada.'

To this group of small subtriangular valve-like bodies, obliquely semi-

circular or semi-elliptical, with straight, hinge-line and more or less definite umbo, belong (1) *Lepiditta alata*, M., 'Tr. R. S., Can.,' vol. iii. 1885, sect. 4, p. 61, pl. vi., figs. 16, 16*a* ; (2) *L. curta*, M., p. 62, pl. vi., fig. 17 ; (3) *Lepidilla anomala*, M., p. 62, pl. vi., figs. 18, 18 *a*, *b*, *c* ; (4) *Lepiditta sigillata*, M., vol. xi. 1894, sect. 4, p. 99, pl. xvii., fig. 1 ; (5) *L. auriculata*, M., p. 99, pl. xvii., figs. 2, 2 *a*, *b*. Some of these were referred to by us in the Sixth Report (for 1888), p. 174.

§ III. 1889. *Rhachura venosa*, Scudder, 1878, 'Proceed. Boston Soc. Nat. Hist.,' vol. xix. p. 296, pl. ix., figs. 3, 3*a* (referred to in our Report for 1883, p. 216). Dr. A. S. Packard, having received from M. Gurley some imperfect specimens found in the Middle Coal-measures, Danville, Illinois, describes them as being parts of a carapace, probably a little over three inches long, and three caudal spines, also rather obscure ('Proceed. Boston Soc. Nat. Hist.,' vol. xxiv. 1889, pp. 212, 213).

§ IV. 1893. *Rhinocaris columbina*.—Mr. J. M. Clarke has contributed a paper 'On the Structure of the Carapace in the Devonian Crustacean *Rhinocaris*, and the relation of the Genus to *Mesothyra* and the *Phyllocarida*,' with illustrative cuts, published in the 'American Naturalist,' September 1, 1893, pp. 793-801. The carapace-valves of *Rhinocaris columbina* (J. M. C., 'Palæont. New York,' vol. vii. 1888, pp. lviii. and 195-197) are described from better specimens, which show it to be a bivalved (not univalved) form, and as having a narrow, median plate, of which there is evidence in *Mesothyra*, making a double dorsal suture. There is also a long, narrow, leaf-like rostrum inserted between the valves in front. The relationship of this form with *Mesothyra* and *Tropidocaris* is dwelt upon. The author thinks that *Dithyrocaris* and *Emmelezoe* have some affinity with it. *Rhinocaris* and *Mesothyra* are regarded as typical members of the family *Rhinocaridæ*. We may mention that Dr. Matthew regards his *Ceratiocaris pusilla* from the Silurian of New Brunswick (see 'Trans. Roy. Soc., Canada,' vol. vi. 1888, sect. 4, p. 56, pl. iv., fig. 2 ; and our Seventh Report (for 1889), p. 64, as *Rhinocaris*.

§ V. 1895. *Emmelezoe Lindstroemi*.—Since our Twelfth Report, presented to the British Association at Ipswich in 1895, the Swedish Phyllocarids mentioned in that Report as having been found by Dr. Gustav Lindström in the Upper Silurian beds at Lau, Gothland, have been duly described and figured in the 'Geological Magazine,' decade 4, vol. ii., No. 378 ; December, 1895, pp. 540, 541, pl. xv., figs. 2*a*–2*d*, as *Emmelezoe Lindstroemi*, J. & W. The fish remains (*Cyathaspis*) and other fossils associated with it are mentioned in detail by G. Lindström in the 'Bihang till K. Svensk. Vet.-Akad. Handl.' vol. xxi. part 4, No. 3, 1895, pp. 11, 12.

Mr. J. M. Clarke has suggested at p. 801 of his memoir mentioned in § IV. that the oculate genus *Emmelezoe* may have some relationship to the group to which *Rhinocaris* belongs.

§ VI. 1895. *Pinnocaris Lapworthi*.—This genus, represented by its only known species, *P. Lapworthi*, has been carefully examined by Woodward and Jones, and several specimens described, selected from a large number in Mrs. Robert Gray's collection at Edinburgh. This memoir appeared in the 'Geological Magazine,' decade 4, vol. ii. 1895, pp. 542–545, pl. xv., figs. 5–10. Excepting one specimen from the Upper Silurian of Kendal, Westmorland, all the known specimens are

from the Lower Silurian of Girvan, Ayrshire, where Mrs. Gray has made a large collection.

The peculiar 'corded' dorsal margin of the valves may have reference to some longitudinal, narrow, intermediate ligament or plate, as in *Rhinocaris* and *Mesothyra.*

§ VII. 1895. A new species of *Ceratiocaris* (*C. reticosa*, J. & W.), preserved in the Museum of the Geological Survey, was described in the 'Geological Magazine,' decade 4, 1895, vol. ii. pp. 539, 540, pl. xv., figs. 1*a*, 1*b*. It is from the Silurian beds of Ludlow, Shropshire, and is allied to *C. cassioides*, from that locality. Traces of a peculiar reticulate sculpture constitute its distinguishing feature.

§ VIII. 1895. *Lingulocaris.*—In the same number (378) of the 'Geological Magazine,' 1895, at pp. 541, 542, a specimen of *Lingulocaris linguIæcomes*, Salter, belonging to the Rev. G. C. H. Pollen, S.J., F.G.S., was figured and described. It came from Capel Arthog, North Wales, probably from the Ffestiniog or middle division of the Lingula-flags. Hence we may add '*Lingulocaris*' to '*Hymenocaris*' for that formation at p. 425 of our Twelfth Report (fifth line from the bottom).

§ IX. 1896. Devonian species of *Ceratiocaris* (?).—In the 'Monograph of the Devonian Fauna of the South of England,' Palæont. Soc., vol. iii. part 1, 1896, the Rev. G. F. Whidborne describes and figures three obscure casts of *Ceratiocaris*, one, *C.* (?) *subquadrata*, sp. nov., p. 7, pl. i., fig. 5, from East Anstey; another, *Ceratiocaris* (?) sp., p. 8, pl. i., fig. 6, from Sloly; and the third, somewhat indistinct specimen, namely, *Ceratiocaris* (?), sp., p. 8, pl. ii., fig. 12, from Croyde.

§ X. 1896. *Entomocaris and Ceratiocaris.*—A collection of Ceratiocaris-like Crustaceans from the Lower Helderberg Formation (Upper Silurian), near Waubeka, Wisconsin, has afforded Mr. R. P. Whitfield, of the American Natural-History Museum, New York, the opportunity of determining two new species of *Ceratiocaris*, and a new genus (*Entomocaris*), allied to *Ceratiocaris*, but differing from it by the carapace-valves being 'strongly curved in front and behind on the dorsal margin,' and by the posterior margin not being truncate, as in *Ceratiocaris*, but obtusely rounded. *Entomocaris Telleri*, Whitfield (p. 300), is figured in pl. xii., of full size, but slightly distorted by pressure. Including the four exposed body-segments and the trifid appendage, it is about 21 centimetres (about 8 inches) long; and the valves are about 13½ centimetres long by about 6½ high. Some indications of the swimming-feet attached to the body are visible where one valve has been partially broken away from the internal cast. Some mandibles, supposed to belong to this species, are shown in pl. xiv., figs. 1, 2; and the caudal appendages in fig. 9.

Ceratiocaris Monroei, Whitfield (p. 301, pl. xiii., figs. 1–5, and pl. xiv., figs. 3–8), is carefully described from one nearly perfect and an imperfect specimen, together with body-segments, caudal appendages, and some mandibles. The carapace-valves seem to have been about 7½ centimetres long and 4 high.

Ceratiocaris poduriformis, Whitfield (p. 302, pl. xiv., fig. 10), is represented by a small specimen of abdominal segments and caudal spines.

§ XI. 1896 *Echinocaris Whidbornei*, J. and W., noticed in our Seventh Report (for 1889), p. 63, has been redescribed and refigured by

the Rev. G. F. Whidborne in the 'Monogr. Devonian Fauna, S. England,' Pal. Soc., vol. iii. part 1, 1896, p. 6, pl. i., fig. 3.

Within the last few months Ananda K. Coomáry-Swámy, Esq., of Warplesdon, has fortunately obtained a very interesting specimen of this *Echinocaris* from the Sloly mudstone, showing, on the two counterparts of the little split slab, two individuals, each having the same characters as the specimen first described in the 'Geological Magazine,' decade 3, vol. vi. 1889, p. 385, pl. xi., fig. 1. Though rather narrowed by oblique pressure, the valves are equal in breadth to those of the first specimen. An additional feature of interest is seen in some body-segments, five in one individual and three in the other. In each case, though the series of segments is not complete either at beginning or end, they are characteristically like those of *Echinocaris*, the distal edges bearing tubercles, the equivalents of spinules.

§ XII. 1896. *Caryocaris.*—In the 'Journal of Geology,' Chicago, vol. iv. 1896, p. 85, Dr. R. R. Gurley has described *Caryocaris* as the 'lateral appendages' of the 'polypary' of a Graptolite! *Caryocaris* was referred to by us in the First and Seventh Reports (for 1883 and 1891), and was described in detail and figured in the 'Monogr. Brit. Palæoz. Phyllocarida,' Pal. Soc., 1892, p. 89 *et seq.*, pl. xiv., figs. 11–18.

§ XIII. 1897. A new locality in Nova Scotia has been determined by Sir William Dawson for *Estheria Dawsoni*, namely East Branch, East River, Pictou County, Lower Carboniferous. Several casts and impressions of small valves, not more than two millimetres long, occur on the bed-planes of a dark-red Lower-Carboniferous shale. Former occurrences of this species were noticed in our Report (Eleventh) for 1894.

Irish Elk Remains.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), his Honour DEEMSTER GILL, Mr. G. W. LAMPLUGH, Rev. E. B. SAVAGE, *and* Mr. P. M. C. KERMODE (*Secretary*), *appointed to examine the Conditions under which remains of the Irish Elk are found in the Isle of Man.*

As the elk remains in the Isle of Man have only been met with in curragh lands where it is not possible to excavate for them till the later part of summer (unless in an unusually dry season), the Committee have not been able to accomplish much before July 1, by which date the report is presented.

An attempt was made in the first place to examine the spot at Ballaugh where the skeleton, now set up in Edinburgh Museum, was found in 1819.[1]

This was in the Loughan-ruy, on the farm of Ballaterson, eastward of the Parish Church, Ballaugh. It is one of several shallow depressions in a drift gravel platform, and measures about 120 yards by 40. It lies about 50 yards west of the Ballacrye Road, leading from the highway to the seashore, and has a boundary fence across the pool at its southern end (Ordnance Sheet, iv. 10 (825)).

[1] See Professor Owen, *British Association Report*, 1843, p. 237.

Permission having been obtained from the proprietor and occupier of the land, some trial excavations were made on May 13 and 14, but the water prevented our sinking to any depth except at the edge (S.W.) of the hollow, where we penetrated to over 7 feet with the following results :—

Loughan-ruy Ballaterson, Ballaugh.

	Thickness of bed Ft. in.	Depth from surface Ft. in.
A. Peat	1 6	1 6
B. Sand, yellow	1 0	2 6
C. Sandy silt, grey (with *Salix herbacea* and *Lepidurus* (*Apus*) *glacialis*)	2 6	5 0
D. Loamy peat	0 8	5 8
E. Gravel	1 0	6 8
F. Marl ('Chara Marl')	0 4	7 0
G. Sharp sand and gravel	0 6 and more.	
Depth excavated	7 6	

Examples from these different beds were forwarded to the officers of the Geological Survey for examination, and we are indebted to Mr. James Bennie, of Edinburgh, who undertook the laborious washing and sorting of the material, and to Mr. Clement Reid for his report upon them, which we append.

On June 24 further excavations were attempted across the bed of the pool, but the inflowing water prevented any results ; nor is it expected that the necessary depth can be attained till the end of July or the middle of August. It is hoped that further work will have been possible before the meeting of the Association, although the results cannot be attained in time to incorporate with this report.[1]

The Committee ask for reappointment. They propose to excavate in the autumn at Loughan-ruy to the full depth of about 18 feet, at which the Edinburgh specimen was found. The bones were apparently obtained from the marl represented by the bed F of our section, this marl evidently thinning off towards the edge of the hollow. Many skulls, bones, and antlers are said to have been left. The Committee propose also to excavate at Kentraugh, in the south of the island, where antlers have been met with ; and at Ballalough, near St. John's, and elsewhere, where remains have been reported, with the hope of discovering such remains *in situ*, so that a full examination of the accompanying fauna and flora may be obtained.

It will be seen that the results of this examination are of considerable importance. The little Arctic crustacean *Lepidurus glacialis* was first found in the Isle of Man two or three years ago in the peaty material obtained from a well on the gravel platform at Kirk Michael,[2] and had not hitherto been discovered so far southward in Great Britain. In that instance the conditions were unfavourable for the investigation of the deposit which contained it, so that our discovery of its remains at Loughan-

[1] Such further work at Ballalough, near Peel, has proved successful, a fairly perfect skeleton—with, however, the skull missing and some of the bones decayed—having been unearthed. Full details will be given in our next year's Report.—October 1897.

[2] *Annual Report of Geological Survey for* 1895, p. 13.

ruy, associated, as at Kirk Michael, with *Salix herbacea*, will afford an opportunity for a closer study of the conditions under which it occurs. As Mr. Reid points out, it is especially desirable to investigate the relations of this Arctic fauna to the beds containing the elk remains.

The following is Mr. Clement Reid's report :—

"The following species of plants and animals were obtained on washing samples of the deposits. Beds C, D, and F are all worthy of closer examination; for it is important to ascertain whether there is any evidence in the Isle of Man of a mild period after the melting of the ice, and before the deposition of the bed with Arctic willows. If the shell-marl (F) containing the *Megaceros* remains was formed during a mild interval, the complete disappearance of the Irish elk, so difficult to understand, may be due to cold or to scarcity of food during a less genial period. This point has never been cleared up in Ireland, notwithstanding the numerous remains of the Irish elk that have there been obtained.

Bed A.

Ranunculus flammula, *L.*	Hydrocotyle vulgaris, *L.*
Potentilla tormentilla, *L.*	Potamogeton, *sp.*

"Also caddis cases and eggs of insects.

"The plants are all common Isle of Man species.

Bed C.

Poterium officinale.	Moss.
Salix herbacea, *L.*	Lepidurus (Apus) glacialis.
Carex, *sp.*	Daphne (winter eggs).
Schœnus ?	

"Numerous leaves of the dwarf Arctic willow *Salix herbacea* and fragments of the Arctic crustacean *Apus glacialis*, neither of them now living in the Isle of Man, point to climatic conditions considerably more severe than those now holding in the district.

Bed D.

Ranunculus aquatilis, *L.*	Potamogeton crispus, *L.*
,, flammula, *L.*	Carex.
,, repens, *L.*	Chara.
Littorella lacustris, *L.*	Beetle (elytron).

"The plants are widely distributed species still living in the Isle of Man. *Littorella* is usually northern.

Bed F.

Ranunculus aquatilis, *L.*	Chara, 2 *sp.*
,, flammula, *L.*	Insect remains.

"This marl thus far has yielded nothing to indicate the climatic conditions."

Erratic Blocks of the British Isles.—Second Report of the Committee, consisting of Professor E. HULL (*Chairman*), Professor T. G. BONNEY, Mr. P. F. KENDALL (*Secretary*), Mr. C. E. DE RANCE, Professor W. J. SOLLAS, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Mr. J. HORNE, Mr. DUGALD BELL, Mr. F. M. BURTON, *and* Mr. J. LOMAS, *to investigate the Erratic Blocks of the British Isles and to take measures for their preservation.*

THE operations of the Committee during the year have been less productive of immediate results than was anticipated.

The number of boulders recorded has been small, but several facts of great interest have been brought to light. The diminution is due principally to the fact that a large section of the work which is carried out in Yorkshire, viz., the enumeration of the boulders on the coast of Holderness, has been carried to virtual completion, but other contributory causes have been the inability of the Secretary to devote so large an amount of time as he had hoped to the work of the Committee, and the severe loss sustained by the Yorkshire Boulder Committee in the death of their most capable and active Honorary Secretary, Mr. Thomas Tate, F.G.S. The respective secretaries of the Lincolnshire Boulder Committee and the Geological Section of the Belfast Naturalists' Field Club have been unable to prepare their reports in time for publication this year.

The first feature of importance to be noticed is the large number of additional records of Shap granite boulders; the occurrence of this rock in Weardale is interesting, as showing the broadening of the area of dispersion after the Pennine Chain was crossed.

Dr. Ricketts' observation of many pebbles of Serpentine at Birkenhead is remarkable, as only one fragment of that petrological type appears to have been observed previously in the area of Lancashire and Cheshire.

The occurrence of pebbles of chalk and flint in North-Western Nottinghamshire is a fact of importance, and may perhaps be taken to indicate an extension of the chalky Boulder-clay.

The Noblethorpe erratic belongs evidently to the same dispersion as the remarkable group of erratics in the Royston district, reported upon two years ago, but it is several miles further west than any boulders previously recorded in the district.

Some noteworthy additions are made to our knowledge of the distribution of the now well-known Norwegian rocks, the Augite-syenite of Laurvik, and the Rhomb-porphyries of the Christiania district. Mr. Kendall has found the former at Saltburn and the latter at Staithes, those being the most northerly stations at which they have been found. Both were beach pebbles, but the travel of beaches on that coast is from north to south, so there is no fear of their being wrongly ascribed to a position to northward of their original locus as boulders.

Mr. Stather has found both rocks as boulders *in situ* in a lower bed of Boulder-clay at Louth in Lincolnshire.

Far exceeding this in interest, however, is the recognition by an eminent Swedish geologist, Dr. Munthe, of two rocks in Mr. Stather's collection, whose place of origin is on the shores of the Baltic. A disposition has been manifested to assume that, because the only Scandinavian

rocks that have been definitely identified among the erratics of our East Coast were from the neighbourhood of Christiania, none from other localities existed; this fortunate discovery shows that assumption to have been unwarranted.

The investigations of Mr. Stather have brought out the remarkable fact that the chalk *Belemnitellæ* found in the Yorkshire drift are referable to a species which has never been found in the Chalk of the district. This fact is of great significance.

CHESHIRE.

Reported by Dr. C. RICKETTS, *M.D., F.G.S., per Glacialists' Association.*

Birkenhead, Price Street—

14 small pebbles of serpentine.

DURHAM.

Reported by Dr. R. TAYLOR MANSON.

Bishop Auckland Park, beside a small tributary of the River Gaunless—

1 Shap granite (now removed to the garden of Mr. R. Nelson, J.P.).

Etherley, Flashes Farm—

1 Shap granite (Mr. Nelson states that it is generally supposed to have been brought from the Tees for use in a cheese-press. Another boulder on the same farm is known to have been brought from Towler Hill, near Barnard Castle).

LINCOLNSHIRE.

Reported by Mr. J. W. STATHER, *F.G.S.*

Louth, Brick-pit in James Street.—A section 50 feet in depth shows two distinct superposed beds of Boulder-clay; in the lower, 20 feet, besides many well striated boulders of Mountain Limestone :—

1 Augite-syenite (Laurvikite);
1 Rhomb-porphyry. (Both of these were found actually embedded in the clay.)

NOTTINGHAMSHIRE.

Reported by Mr. H. H. CORBETT, *M.R.C.S.*

Harworth, near Bawtry.—In the lower beds of clay at the Brickyard fragments of chalk and flint occur.

In a gravel pit between Harworth and Bawtry the stones are almost exclusively Triassic quartzite pebbles, but at the base, resting on Triassic sandstone, are large boulders of Magnesian Limestone containing *Axinus.*

YORKSHIRE.[1]

Communicated by the Yorkshire Boulder Committee.
Reported by Rev. C. T. PRATT.

Banks Bottoms, Noblethorpe—

1 Cleaved volcanic ash (probably Lake District), now removed to the entrance to the Museum at Cawthorne.

[1] This report will be published *in extenso* in the *Naturalist.*

Reported by Dr. J. TEMPEST ANDERSON.

High Borough (Roman Camp), near Grosmont, 345 *feet above O.D.*—

1 Shap granite. Now removed to Grosmont Churchyard.

Reported by Mr. W. GREGSON, *F.G.S.*

Cotherstone, 3 *miles N.W. of Barnard Castle, about* 600 *feet above O.D.*—

1 Shap granite.

Whashton, midway between Richmond and Barnard Castle, about 700 *feet above O.D.*—

1 Shap granite.

Reported by Mr. H. H. CORBETT, *M.R.C.S.*

Cutworth and Sprotborough—

1 Shap granite; 2 orthoclase-porphyries; 3 diorites; 3 basalts; 1 carboniferous grit; 1 weathered granite; 1 mountain limestone.

Balby.—At the Balby Brickworks—

1 basalt; 1 granophyre; 2 granites; 1 gneiss; 1 volcanic agglomerate; 1 quartz-porphyry.

Doncaster.—Found in excavating behind the Old Free Library—

1 basalt.

Reported by Mr. J. FARRAH.

Claro Hill—

2 Shap granites. Now removed to the entrance to the Workhouse at Marton cum-Grafton.

Reported by Mr. P. F. KENDALL, *F.G.S.*

Saltburn—

1 Augite-syenite (Laurvikite).

Staithes—

1 Rhomb-porphyry. These two erratics were found as pebbles on the beach; they are the most northerly occurrences of the respective rocks.

Reported by the Hull Geological Society.
By Mr. F. F. WALTON, *F.G.S.*

Scarborough.—In drift 12 feet from the surface of the scarped cliff at Castlefield—

1 Estuarine sandstone.

By Mr. J. W. STATHER, *F.G.S.*

Holderness—Dr. Munthe of Upsala University recognised in Mr. Stather's collection from the Boulder-clay of Holderness two rocks from localities adjacent to the Baltic—

1 'Post-Archæan granite' from Angermanland or Aland, Sweden; 1 Hallëflinta (? from Smaland, Sweden).

Holderness and South Ferriby—The Chalk belemnites which are fairly common in the Boulder-clays here have been determined by Mr. Jukes

Browne as *Belemnitella lanceolata* (Schloth). This belemnite is not recorded from the Yorkshire Chalk, but *B. quadrata*, which is exceedingly plentiful in the Upper Chalk of Yorkshire, I have not seen in the clays.

Isle of Man.

Reported by Rev. S. N. Harrison.

Kirk Bride shore—

1 Shap granite, subangular, striated.

Port Lewaigue shore—

1 Shap granite.

The Necessity for the Immediate Investigation of the Biology of Oceanic Islands.—Report of the Committee, consisting of Sir W. H. Flower (*Chairman*), Professor A. C. Haddon (*Secretary*), Mr. G. C. Bourne, Dr. H. O. Forbes, Professor W. A. Herdman, Dr. John Murray, Professor Newton, Mr. A. E. Shipley, *and* Professor W. F. R. Weldon. (*Drawn up by the Secretary.*)

The Committee are not able to report any practical results from their appeal of last year, but they hope, by keeping the matter before the public, to eventually arouse an interest in the important objects which the Committee have in view.

Although nothing definite has been accomplished this year, the Secretary, acting in co-operation with a committee in Cambridge, is organising an expedition, which will start next February, for the purpose of continuing his researches on the Anthropology of the Torres Straits Islanders. These people occupy an area between that held by the Papuans on the one hand and by the Australians on the other; and, although it is well known that they belong essentially to the Melanesian race, it is important to finally establish their ethnic affinities. The natives are rapidly disappearing, or are becoming modified by mixture with other races, and thus there is an immediate need that they should be thoroughly studied before it is too late to make accurate anthropological observations.

Mr. Sidney H. Ray, the recognised expert on the languages of Oceania, will accompany the expedition. He has already published studies on the two languages of Torres Straits and on that of the neighbouring coast of New Guinea.[1] The other members of the expedition will consist of men trained in various branches of biology, particularly in anthropology and physiology. So far as opportunity offers, various branches of the anthropology of the natives will be studied and numerous photographs taken. All the collections of objects illustrating the anthropography and ethnography of the Torres Straits Islanders will be presented to appropriate museums.

The zoology and botany of the islands will not be neglected, but the services of a naturalist have not yet been secured.

[1] *Proc. Royal Irish Acad.*, 3rd ser. vol. ii. (1893), pp. 463–616; vol. iv. (1896), pp. 119–373.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor W. A. HERDMAN, Professor E. RAY LANKESTER, Professor W. F. R. WELDON, Professor S. J. HICKSON, Mr. A. SEDGWICK, Professor W. C. MCINTOSH, Mr. W. E HOYLE, *and* Mr. PERCY SLADEN (*Secretary*).

THE table in the Naples Zoological Station hired by the British Association has been granted during the past year to Mr. H. M. Vernon, Miss A. Vickers, and Professor W. F. R. Weldon.

Mr. Vernon has occupied the table during the months of April, May, and June, and continued his investigations on the effects of environment upon the development of Echinoderm larvæ. He has furnished a preliminary report upon his work, which will be found appended.

Miss Vickers, who was engaged in studying the Algæ of the Gulf of Naples, has, through the kindness of Professor Dohrn, occupied the table for nearly two months concurrently with Mr. Vernon. Your Committee desire to express their appreciation of this generous act of consideration on the part of Professor Dohrn. Owing to the early date of the meeting this year Miss Vickers's report has not yet been received.

Professor Weldon proposed to occupy the table during the months of July, August, and September, to investigate the phenomena of variation in Crustacea; and the result of his work will of necessity form part of next year's report.

An application for permission to use the table during the ensuing year has been received from Mr. J. Parkinson, for the purpose of making investigations on the budding of the compound Ascidians, especially of the Botryllids. He wishes to go to Naples at the beginning of October and to remain six months.

An application has also been received from Mr. James F. Gemmill, Lecturer on Vertebrate Embryology in the University of Glasgow, for permission to use the table during the months of September and October. In support of this application Professor Dohrn has kindly written to say that he will be glad to allow Mr. Gemmill to occupy a table, if approved by the Committee, concurrently with any other appointment made by the Committee.

Other applications have also been received; in fact, more candidates for the table have recently come forward than at any previous period.

Your Committee trust that the General Committee will sanction the payment of the grant of 100*l*., as in previous years, for the hire of the table in the Zoological Station at Naples.

On April 14 there was commemorated at Naples the twenty-fifth anniversary of the foundation of the Zoological Station. The occasion was observed with much ceremony; and a number of eminent scientific men and high officers of State assembled to congratulate Professor Dohrn

and to confer upon him and his colleagues various orders of dignity and academic honours. Among the numerous addresses presented to Professor Dohrn, one, subscribed by more than nineteen hundred naturalists and philosophers from all parts of the world, is sufficient to indicate the esteem in which the Zoological Station is universally held. In the course of an eloquent speech Professor Dohrn specially acknowledged his gratitude and indebtedness to the British Association for their support, which has extended from the early critical period of the station's existence up to the present time.

The progress of the various publications undertaken by the station is summarised as follows :—

1. Of the 'Fauna und Flora des Golfes von Neapel' the monographs by Dr. G. Jatta on 'I Cefalopodi, Sistematica' (pp. 268, 31 plates), and by Dr. H. Ludwig on 'Seesterne' (pp. 491, 12 plates), have been published.
2. Of the 'Mittheilungen aus der zoologischen Station zu Neapel' vol. xii. part iii., with 7 plates, has been published.
3. Of the 'Zoologischer Jahresbericht' the whole 'Bericht' for 1895 has been published.
4. A new and greatly revised English edition of the 'Guide to the Aquarium' has been published.

The details extracted from the general report of the Zoological Station, which have been courteously furnished by the officers, will be found at the end of this report. They embrace lists (1) of the naturalists who have occupied tables since the last report, and (2) of the works published during 1896 by naturalists who have worked at the Zoological Station.

I. *Report on the Occupation of the Table. By* Mr. H. M. Vernon.

The Conditions of Animal Life in Marine Aquaria.

I was originally appointed to the British Association table at Naples for the months of April and May, but my term was subsequently extended to the end of June. My object in coming to Naples was to continue some work I had been engaged upon during a previous stay at the Zoological Station. This work consisted in an investigation upon the effects of environment upon the development of Echinoderm larvæ. At the present time I am endeavouring to elucidate something as to the conditions of Animal Life—especially as regards those appertaining to Marine Aquaria —by the help of these larvæ, which are obtained very readily by means of artificial fertilisations.

The work consists of two more or less distinct parts—first, of the growing of the larvæ of *Strongylocentrotus lividus* under various conditions, and then preserving and measuring them under the microscope, so as to determine what change, if any, has been produced in their size by the different environmental conditions; and secondly, of the analysis of the various specimens of water in which the larvæ are allowed to develop, so as to determine how the degree of organic impurity of the water affects the growth of the larvæ, and how this impurity may be most effectually, as judged by both chemical and physiological standards, removed.

The analyses of the water thus far made have consisted in determining

only the free ammonia and the albuminoid ammonia present. The method used is the well-known one of distilling off a portion of the water, and determining the ammonia present in the distillate colorimetrically after the addition of Nessler's reagent, and then further distilling after the addition of an alkaline solution of permanganate of potash, thereby obtaining in the distillate what is known as the albuminoid ammonia present in the water. The values thus obtained afford a fair criterion as to the comparative amounts of organic impurity present.

As, at the time of writing, I have been engaged on this work only about two months, the results obtained must necessarily be regarded as of a somewhat preliminary nature. Such as they are, however, they seem to show that the method is one of some value. A good many experiments have been made to determine the most favourable conditions for the removal of the ammonia, which is present in large quantities in the tank water of the Aquarium, by means of vegetable life. It has been found that the alga *Ulva* removes the free ammonia present fairly rapidly, though it has not much influence on the albuminoid ammonia. Indeed, if the amount of this alga taken is more than about one square inch per litre of water this actually increases in amount, presumably owing to the metabolism of the vegetable tissues. The alga acts best in diffused daylight, it being bleached in sunlight. Larvæ allowed to grow in water purified by this moderate amount of alga were found to be 14 per cent. larger than those grown in the unpurified water. If too much alga has been added they are smaller than the normal, or do not develop at all.

Probably vegetable life exerts its influence most powerfully through the agency of minute algæ and diatoms. Thus it was found that every grain of the coarse sand which is placed in the tanks of the Aquarium is covered with a thin layer of algæ and diatoms, and that in water filtered fairly rapidly through a layer of this sand a few inches deep the amount of free ammonia present is diminished to about a fifteenth of its previous amount.

Several other possible means of purification of the water have been examined. Thus it has been found that if water be exposed to sunlight a few days in a flask filled up to the neck, whereby very little surface comes into contact with the air, the amount of ammonia present is, if anything, increased, but yet larvæ subsequently grown in such water are 15 per cent. larger than the normal. Larvæ grown in water which has been exposed to the action of the air as well as the sun in a flat, covered glass jar are, however, rather smaller than the normal, and also the ammonia present in such water is appreciably increased. Larvæ grown in water previously heated to boiling are slightly increased in size.

Again, a series of observations is being made upon the relative capacities for 'fouling' water possessed by various members of the animal kingdom. Various animals of known weights are placed for known times in measured volumes of water, and the increase in the amount of ammonia present is then determined in a portion of the water. In another portion larvæ are allowed to develop, and so by subsequent measurement the adverse effect on their growth of the products of metabolism of the various animals is determined. Still, again, other observations are being made as to the effects upon the growth of the larvæ of the addition of various salts, such as nitrates, nitrites, and ammonium salts, to the water.

In conclusion I wish to offer my thanks to the Committee of the British Association for the privilege of being allowed to hold the table,

and also to the authorities at the Zoological Station at Naples for their invariable kindness and assistance to me in my work.

II. *A List of Naturalists who have worked at the Zoological Station from the end of June* 1896 *to the end of June* 1897.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
907	Stud. P. Dorello	Italy	July 7, 1896	Aug. 21, 1896
908	Prof. S. Apáthy	Hungary	„ 10, „	Oct. 28, „
909	Prof. F. S. Monticelli	Italy	„ 15, „	Nov. 20, „
910	Prof. A. della Valle	Modena	„ 20, „	Sept. 24, „
911	Prof. V. Chmielevsky	Russia	„ 22, „	„ 21, „
912	Dr. A. Romano	Italy	Aug. 1, „	—
913	Dr. V. Diamare	„	„ 1, „	—
914	Dr. A. Russo	„	„ 1, „	Oct. 19, „
915	Prof. S. Trinchese	„	„ 1, „	Dec. 31, „
916	Stud. J. W. Langelaan	Holland	„ 6, „	„ 1, „
917	Dr. Mazza	Italy	„ 12, „	Sept. 3, „
918	Prof. Oltmanns	Baden	Sept. 4, „	Oct. 20, „
919	Dr. H. Boruttan	Prussia	„ 18, „	Nov. 2, „
920	Prof. G. B. Grassi	Rome	„ 20, „	Oct. 1, „
921	Dr. A. Bethe	Strasburg	„ 23, „	Nov. 12, „
922	Stud. O. Fragnito	Italy	„ 24, „	—
923	Dr. M. Bedot	Switzerland	„ 24, „	Oct. 26, „
924	Prof. d'Abundo	Italy	„ 24, „	„ 1, „
925	Prof. Th. Studer	Switzerland	„ 27, „	„ 12, „
926	Prof. Th. Ziehen	Prussia	Oct. 1, „	„ 8, „
927	Mr. L. J. Picton	Oxford	„ 12, „	June 12, „
928	Mag. G. Schneider	Russia	„ 13, „	Mar. 17, 1897
929	Dr. T. Beer	Austria	„ 16, „	Apr. 11, „
930	Dr. A. Krämer	Würtemberg	„ 16, „	Dec. 15, 1896
931	Mr. A. Mordivilko	Russia	Nov. 5, „	Feb. 13, 1897
932	Prof. F. H. Herrick	Smithsonian Instit.	„ 6, „	Dec. 4, 1896
933	Dr. G. Brandes	Prussia	„ 7, „	Apr. 17, 1897
934	Dr. P. Celesia	Italy	„ 10, „	Mar. 29, „
935	Dr. H. Driesch	Hamburg	„ 11, „	May 14, „
936	Dr. C. Herbst	Prussia	„ 11, „	„ 14, „
937	Dr. Vastarini Cresi	Italy	„ 13, „	—
938	Dr. L. Schultze	Prussia	„ 16, „	Feb. 12, „
939	Dr. G. Schischkoff	Bulgaria	Dec. 1, „	—
940	Dr. L. Brüel	Saxony	„ 14, „	—
941	Mr. F. B. Stead	Cambridge	„ 28, „	—
942	Dr. G. Tagliani	Italy	Jan. 1, 1897	—
943	Dr. G. Jatta	Zoological Station	„ 1, „	—
944	Dr. Ph. Barthels	Prussia	„ 11, „	Apr. 21, „
945	Prof. G. Ruge	Holland	„ 11, „	„ 20, „
946	Dr. F. Studnička	Austria	Feb. 15, „	„ 1, „
947	Dr. J. v. Uexküll	Strasburg	„ 19, „	June 8, „
948	Dr. R. Lauterborn	Bavaria	„ 26, „	Apr. 19, „
949	Prof. H. E. Ziegler	Baden	Mar. 3, „	„ 24, „
950	Dr. R. Krause	Prussia	„ 4, „	„ 20, „
951	Prof. K. Kostanecki	Austria	„ 5, „	„ 14, „
952	Dr. M. Siedlecki	„	„ 5, „	May 20, „
953	Dr. O. zur Strassen	Hesse	„ 11, „	Apr. 25, „
954	Stud. W. Paulcke	Baden	„ 11, „	„ 19, „
955	Prof. V. Häcker	Würtemberg	„ 18, „	„ 19, „
956	Dr. E. Meek	Smithsonian Instit.	„ 19, „	May 5, „
957	Dr. J. Sobotta	Prussia	„ 22, „	„ 2, „
958	Dr. Sidney Wolf	Strasburg	„ 29, „	Apr. 12, „

II. A LIST OF NATURALISTS—*continued.*

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
959	Miss Vickers	British Association	Apr. 3, 1897	May 26, 1897
960	Prof. W. His	Saxony	„ 6, „	Apr. 19, „
961	Mr. H. M. Vernon	British Association	„ 8, „	—
962	Dr. J. Graham	Columbia College	„ 9, „	May 14, „
963	Dr. H. Jennings	Smithsonian Instit.	„ 10, „	June 25, „
964	Dr. Fischel	Austria	„ 10, „	May 29, „
965	Dr. A. Taquin	Belgium	„ 15, „	—
966	Prof. A. Sewertzoff	Russia	„ 16, „	—
967	Dr. H. Neal	Smithsonian Instit.	„ 16, „	May 29, „
968	Dr. E. Rousseau	Belgium	May 3, „	—
969	Prof. P. Samassa	Baden	„ 24, „	June 13, „

III. *A List of Papers which were published in the Year* 1896 *by the Naturalists who have occupied Tables in the Zoological Station.*

P. Samassa . . . Studien über den Einfluss des Dotters auf die Gastrulation und die Bildung der primären Keimblätter der Wirbelthiere. I. Selachier, 'Arch. f. Entwickelungs-Mechanik.,' B. 2, 1895

G. Bidder . . . The collar-cells of Heterocœla. 'Quart. Jour. Micr. Sc., vol. 38, 1895.

C. Herbst . . . Ueber die Regeneration von antennenähnlichen Organen an Stelle von Augen. 1. Mittheilung. 'Arch. f. Entw.-Mech.,' B. 2, 1896.

„ . . . Experimentelle Untersuchungen über den Einfluss der veränderten chemischen Zusammensetzung des umgehenden Mediums auf die Entwickelung der Thiere. 3.–6. Theil. *Ibid.*

„ . . . Ueber Regeneration von antennenähnlichen Organen. 'Vierteljahrsschrift der Naturf. Ges. Zürich,' B. 41, 1896.

V. Willem und Schoenlein Beobachtungen über Blutkreislauf u. Respiration bei einigen Fischen. 'Zeitschr. f. Biologie,' B. 32, 1896.

N. Iwanzoff . . . Ueber den Bau, die Wirkungsweise u. die Entwickelung der Nesselkapseln von Cœlenteraten. 'Anat. Anz.,' B. 11, 1896, u. 'Bull. Soc. Natural. Moscou,' vol. 10, 1896.

E. MacBride . . . The development of Asterina gibbosa. 'Quart. Jour. Micr. Sc.,' vol. 38, 1896.

J. E. S. Moore . . On the structural changes in the Reproductive Cells during the spermatogenesis of Elasmobranchs. *Ibid.*

M. v. Lenhossék . . Histologische Untersuchungen am Sehlappen der Cephalopoden. 'Arch. Mikr. Anat.,' B. 47, 1896.

E. Drechsel . . . Beiträge zur Chemie einiger Seethiere. 'Zeitschr. f. Biologie,' B. 33, 1896.

J. v. Uexküll . . . Zur Muskel- u. Nervenphysiologie von Sipunculus nudus. *Ibid.*

„ . . . Ueber die Function der Poli'schen Blasen am Kauapparat der regulären Seeigel. 'Mitt. Zoolog. Station Neapel,' B. 12, 1896.

A. Russo . . . Nuovo contributo all' embriologia degli Echinodermi. 'Boll. Soc. Nat. Napoli,' vol. 10, 1896.

„ . . . Per un recente lavoro di E. W. MacBride sullo sviluppo dell' Asterina gibbosa. *Ibid.*

T. H. Morgan . . . The number of cells in larvæ from isolated blastomeres of Amphioxus. 'Arch. f. Entw.-Mechanik.,' B. 3, 1896.

„ . . . The production of artificial astrosphæres. *Ibid.*

H. Driesch . . .	Die taktische Reizbarkeit der Mesenchymzellen von Echinus microtuberculatus. *Ibid.*
„ . . .	Betrachtungen über die Organisation des Eies u.s.w. *Ibid.* B. 4.
„ . . .	Zur Analyse der Reparationsbedingungen bei Tubularia. 'Vierteljahrsschrift Nat. Ges. Zürich,' B. 41, 1896.
G. v. Koch . . .	Kleinere Mittheilungen über Korallen. (10. Zwischenknospung bei recenten Korallen. 11. Knospung von Favia cavernosa.) 'Morphol. Jahrbuch,' B. 24, 1896.
A. Borgert . . .	Zur Fortpflanzung der tripyleen Radiolarien (Phæodarien). 'Zool. Anz.,' B. 19, 1896.
„ . . .	Die Doliolum-Ausbeute des 'Vettor Pisani.' 'Zool. Jahrbücher,' Abth. f. Systematik, B. 9, 1896.
J. Sobotta . . .	Zur Entwickelung von Belone. 'Verh. Anat. Ges.,' 1896.
M. Wheeler . . .	The sexual phases of Myzostoma. 'Mitth. Zool. Station Neapel,' B. 12, 1896.
L. Neumayer . . .	Der feinere Bau der Selachier-Retina. 'Archiv f. Mikr. Anat.,' B. 48.
H. Ziegler . . .	Die Entstehung des Periblastes bei den Knochenfischen. 'Anat. Anz.,' B. 12, 1896.
„ . . .	Einige Beobachtungen zur Entwickelungsgeschichte der Echinodermen. 'Verh. der deutsch. Zoolog. Ges.,' 6. Vers., 1896 (*partim*).
K. Kostanecki . .	Ueber die Gestalt der Centrosomen im befruchteten Seeigeln. 'Anat. Hefte, Merkel u. Bonnet,' B. 7, 1896.
F. S. Monticelli . .	Adelotacta Zoologica. 'Mitth. Zool. Station Neapel,' B. 12, 1896.
D. N. Voinov . . .	Halacarus Trouessarti, nouvelle espèce d'Halacarides de la Méditerranée. 'Bull. Soc. Zool. de France,' 1896.
V. Faussek . . .	Zur Cephalopodenentwickelung. 'Zool. Anz.,' 1896.
S. Pereyaslawzewa . .	Mémoire sur l'organisation de la Nerilla antennata. O. Schmidt, 'Ann. Sc. Nat. Zool.,' t. 1, 1896.
V. Häcker . . .	Pelagische Polychætenlarven. Zur Kenntniss des Neapler Frühjahr-Auftriebes. 'Zeitschr. f. wiss. Zoologie,' B. 42, 1896.
P. Ziegenhagen . .	Ueber Entwickelung der Circulation bei Teleostiern, insbesondere bei Belone. 'Verhandl. der Anatom. Ges.,' 1896.

The Zoology of the Sandwich Islands.—Seventh Report of the Committee, consisting of Professor A. NEWTON (*Chairman*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, Mr. O. SALVIN, Dr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

THE Committee was appointed in 1890, and has been annually re-appointed. It has continued to work in conjunction with a Committee appointed by the Royal Society for the same purposes. Since the last Report Mr. R. C. L. Perkins was maintained at work in the islands till March last by aid of the Bernice P. Bishop Museum in Honolulu. He has now returned to England, and is engaged in arranging his second set of collections for being worked out. The Committee is endeavouring to get all the material reported on by competent specialists, several of whom have made considerable progress. The work to be done is, however, so extensive, especially in arthropods, that the Committee anticipates a period of two years must elapse before the work can be satisfactorily completed. Papers, of a preliminary nature, have been published since the last Report by Mr. E. R. Sykes ('Proc. Malacol. Soc.,' 1896), by

Mr. R. C. L. Perkins ('Entomol. Monthly Mag.,' 1896), and by D. Sharp ('Entomol. Monthly Mag.,' 1896). The Committee requests reappointment to enable it to complete its work.

Zoological Bibliography and Publication.—Second Report of the Committee, consisting of Sir W. H. FLOWER (*Chairman*), Professor W. A. HERDMAN, Mr. W. E. HOYLE, Dr. P. L. SCLATER, Mr. ADAM SEDGWICK, Dr. D. SHARP, Mr. C. D. SHERBORN, Rev. T. R. R. STEBBING, Professor W. F. R. WELDON, *and* Mr. F. A. BATHER (*Secretary*).

THE Report presented in 1896 stated that this Committee was issuing two circulars: (I.) Questions concerning general principles of Bibliography and Publication, sent to experts and leading zoologists; (II.) Suggestions concerning various cognate matters 'wholly within the control of editors and publishing committees,' sent to the editors of all publications connected with zoology.

Circular I. has been sent to 115 zoologists, the majority of whom have had practical experience in Bibliography. From 36 of these, in various parts of the world, replies have been received, containing, in many cases, a detailed discussion and practical suggestions of much value. A digest of these replies is being drawn up, and the Committee hopes to furnish a definite Report thereon next year. Meanwhile certain of the suggestions and criticisms received have greatly helped the Committee in its consideration of the replies to Circular II.

To this latter Circular and its strictly practical proposals the Committee thinks it advisable to confine attention for the present. Circular II. has been sent to the editors of nearly all the publications listed in the 'Zoological Record,' viz., to some 800, the exceptions being those whose addresses could not be ascertained; it has also been sent to the editors of various publications not hitherto included in the 'Zoological Record' list, *e.g.*, all zoological publications recently started.

Replies were not specially solicited, but comments have been received from 39 editors or publishing bodies, to all of whom the Committee desires to express its thanks. Among them may be mentioned: the R. Physical Society of Edinburgh, the Natural History Society of Glasgow, the Cambridge Philosophical Society, the Entomological Society of London, the Liverpool Biological Society; 'Nature,' 'Natural Science,' 'The Zoologist,' 'The Entomologist,' 'The Journal of Malacology,' 'Journal of Physiology,' Cambridge; The R. Asiatic Society, Ceylon Branch; K. Akademie der Wissenschaften zu Berlin; K. Zool. u. Anthrop.-Ethnogr. Museum zu Dresden; Zoological Station in Naples; R. Soc. Scientiarum Bohemica; Physikalisch-ökonomische Gesellschaft zu Königsberg; R. Soc. Sciences in Upsala; Société Impériale des Naturalistes de Moscou; Koninklijke Akademie van Wetenschappen, Amsterdam; Geological Society of America, Philadelphia Academy of Natural Sciences, Essex Institute, Cincinnati Society of Natural History, Natural History Society of New Brunswick, 'Science,' 'Bulletin of American Palæontology,' 'Entomological News.' All these replies are favourable to the suggestions of the Committee in the main, and some even ask for further advice. Exception has, however, been taken by some to suggestions 1, 3, and 7;

while comments have also been made on suggestions 2, 4, and 5. It is proposed to deal with these in order.

First, the Committee wishes to state clearly that it has no wish, even if it had the authority, to lay down laws for zoologists or for publishing bodies and editors. It is, however, plain that many are grateful for some guidance, and the Committee hopes that it may serve as a medium for conveying to those who need it the general opinion of the experienced. There are also difficulties which, though they appear to some insuperable, may possibly be surmounted in ways that have been communicated to the Committee.

> (1) 'That each part of a serial publication should have the date of actual publication, as near as may be, printed on the wrapper, and, when possible, on the last sheet sent to press.'

Five correspondents do not see the use of this, thinking that the date on the wrapper is enough, and that in the case of annual publications the date of the year suffices. The Committee would point out that wrappers are constantly lost in binding, and that periodicals are often broken up by specialists or second-hand booksellers, the consequent loss of date causing much trouble to workers of a later day. To avoid this, the Cincinnati Society of Natural History would add the date at the head of each paper, while 'Natural Science' prints the month and year across every page-opening. Some societies, *e.g.* the Philadelphia Academy, issue a certificate of dates at the end of the volume. The Liverpool Biological Society 'put at the head of each paper the date when it is read, and are willing to add the date when it is printed off': neither of these dates are necessary, and they may be misleading. In most cases the actual day of publication is immaterial, especially in cases where no new species are described, but at least the month should always be given, and the Committee does not see that there need be any difficulty in doing this. If some unforeseen delay does occur, the date can always be rectified with a date-stamp.

> (2) 'That authors' separate copies should be issued with the original pagination and plate-numbers clearly indicated on each page and plate, and with a reference to the original place of publication.'

The Committee believes this to be a most important recommendation, and its view is supported by all the zoologists consulted. Nevertheless, many leading publications continue to issue authors' copies repaged, and often without reference to volume-number, date, or even the name of the periodical. The remedy is so simple that the Committee urgently appeals for its universal application.

> (3) 'That authors' separate copies should not be distributed privately before the paper has been published in the regular manner.'

It is a curious fact that on this question editors take a different line to working zoologists. All the latter who have discussed the matter agree with the Committee as to the extreme inconvenience caused by the general custom. Among the editors, however, nine (*i.e.*, nearly one-quarter) protest against the present recommendation. The objectors represent small societies which publish at lengthy intervals, and their reasons are: that it is not fair to an author to prevent him from receiving

his separate copies for perhaps a year; that it is not to the advantage of science that work should thus be delayed; that a society which did this would receive fewer contributions and lose its members. In brief, the argument is: 'We are too poor to publish properly; therefore we must allow authors to publish improperly.' This form of argument suggests an easy remedy, and one that, on the informal suggestion of the Committee, has already been put into practice by the Liverpool Biological Society and by the R. Physical Society of Edinburgh. The remedy is this:

In cases where a volume or part can only appear at long intervals, each author that requires separate copies of his paper for private distribution before its publication in the volume or part should be permitted them only on this condition—that, for every month before the probable issue of the volume, a certain number of copies—say five—should be placed by him in the hands of the society or its accredited publisher, in order that they may be offered for sale to the public at a fixed price. Further, that the society, for its part, should announce the publication, with price and agent, of their papers to some recognised office, or to some such paper as the 'Zoologischer Anzeiger.' The details of expense must be settled between the author and the society.

(4) 'That it is desirable to express the subject of one's paper in its title, while keeping the title as concise as possible.'

It is satisfactory to find no objections raised to this recommendation, since there is no doubt that there is room for much improvement in this direction. Such phrases as 'Further contributions towards our knowledge of the . . . . ,' or 'Einige Beobachtungen über . . . . ,' or 'Essai d'une Monographie du genre . . . . ' might well be dispensed with as superfluous. The ornithologist who, in 1895, published a book with a title of ninety-one words would seem to have forgotten the functions of a preface.

On the other hand, it is pointed out that certain periodicals, such as the 'Bulletin de la Société Entomologique de France' and the 'Sitzungsberichte der Gesellschaft naturforschender Freunde zu Berlin' publish communications without any title, to the constant confusion of naturalists The Committee begs to urge the reform of this practice, in which it can see no advantage.

(5) 'That new species should be properly diagnosed, and figured when possible.'

The only comment on this is the proposed omission of the words 'when possible.' With this the Committee sympathise, but wish to avoid all appearance of laying down a law that would constantly be broken.

(6) 'That new names should not be proposed in irrelevant footnotes or anonymous paragraphs.'

Naturally nobody supports such actions as are here objected to, but since some have doubted the possibility of the latter, it is as well to state that the suggestion was based on an actual case occurring in the Report of a well-known International Congress. The proposal of a new name, without diagnosis, in a footnote to a student's text-book, or in a short review of a work by another author, is a by no means rare occurrence. The Committee believes that such practices are calculated to throw nomenclature into confusion rather than to advance science.

(7) 'That references to previous publications should be made fully and correctly if possible, in accordance with one of the recognised sets of rules for quotation, such as that recently adopted by the French Zoological Society.'

Dr. Paul Mayer, of Naples, writes : 'Most authors are extremely idle in making good lists of literature themselves, and even oppose my correcting them according to our rules. There ought to be some training in this at our Universities.' This is confirmed by one or two other editors, but not all have the energy of Dr. Mayer. Some, indeed, oppose the word 'fully' on the ground that it leads to waste of time and space. The Committee would explain that the reference to a particular set of rules was intended merely as a guide to those who have not had the training that Dr. Mayer would like to see ; they would also point out, in the words of the editor of the Cincinnati Society of Natural History, that 'what may be intelligible to the specialist is very puzzling to the general student.' Nowadays, when so many zoologists work with the aid of authors' separate copies, it is an enormous convenience to them to have the title of the paper at least indicated, and not merely the volume, date, and pagination given. The Committee, therefore, cannot agree that this suggestion involves a waste of time.

Finally, the Committee recommends that copies of this Report be distributed to the editors of all publications connected with zoology ; and for this purpose it recommends its reappointment with a grant of 6*l*. 1*s*. for expenses of printing and postage.

Bird Migration in Great Britain and Ireland.—Interim Report of the Committee, consisting of Professor NEWTON (*Chairman*), Mr. JOHN CORDEAUX (*Secretary*), Mr. JOHN A. HARVIE-BROWN, Mr. R. M. BARRINGTON, Rev. E. PONSONBY KNUBLEY, *and* Dr. H. O. FORBES, *appointed to work out the details of the Observations of the Migration of Birds at Lighthouses and Lightships*, 1880–87.

IT is with extreme regret that your Committee have to report the serious illness of Mr. William Eagle Clarke, shortly after his return last autumn from the delta of the Rhone, to which his zeal in investigating the subject of Bird Migration had led him at an unhealthy season. In consequence of this illness he has been able to make but little progress in executing the task of working out the details of the Observations already so successfully digested by him, which task had been entrusted to him by your Committee.

It seems quite certain that no useful result could follow from at present placing in other hands any of the records which the Committee possess, even if such a course would be fair to Mr. Clarke, who has already bestowed so much labour and time upon them, and therefore your Committee, in the hope of his eventual recovery, respectfully request reappointment.

Life Conditions of the Oyster: Normal and Abnormal.—Second Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Professor R. BOYCE (*Secretary*), Mr. G. C. BOURNE, *and* Professor C. S. SHERRINGTON, *appointed to Report on the Elucidation of the Life Conditions of the Oyster under Normal and Abnormal Environment, including the Effect of Sewage Matters and Pathogenic Organisms.* (*Drawn up by* Professor HERDMAN *and* Professor BOYCE.)

The Green Disease.

SINCE our Report, read at the Liverpool Meeting of the British Association last September, in which we announced that we had discovered a pale green disease, accompanied by a leucocytosis, in certain American oysters laid down on our coasts, two papers have appeared which require brief notice. One of these is an article by Dr. D. Carazzi in the 'Mittheilungen' of the Naples Zoological Station for 1896, and the other is the 'Supplement to the Report of the Medical Officer for 1894–95,' which deals with oyster culture in relation to disease, and which appeared towards the end of 1896.

Dr. Carazzi has worked with the ordinary European oyster (*Ostrea edulis*) at Spezia. The green oysters which he has investigated are the 'Huîtres de Marennes,' and some oysters of unknown origin which he obtained from the bottom of a yacht. He has also had specimens of the Portuguese oyster, but, so far as appears, no American oysters. He considers that all the green oysters he has examined have been healthy. He has apparently not seen any condition at all resembling the pale chalky green, unhealthy state that we find in certain American oysters, and so he seems inclined to deny its occurrence! We have endeavoured to demonstrate to Dr. Carazzi the existence of this diseased condition by sending him both living specimens and also pieces of the affected mantle, &c., fixed, preserved, and imbedded in paraffin ready for sectioning. Dr. Bulstrode, in the Medical Officer's Report referred to below, has clearly met with the green disease we described last year; and we have also had the satisfaction of showing it to Dr. P. P. C. Hoek, of Helder, who visited our laboratories last February for the purpose of seeing our oyster work. Our specimens and preparations have also been seen at all stages of the investigation by our assistants and colleagues[1] at University College, Liverpool.

The latter of the two works, a book of 174 pages, and many illustrations, consists of reports by Dr. Thorne Thorne, Dr. E. Klein, and Dr. Bulstrode, upon the conditions under which oysters are cultivated and stored, and upon the connection between unhealthy conditions and the presence of pathogenic organisms in the oysters. Although these reports contain little that was not known to those interested in the subject, still they served to draw public attention to what had been only previously known to oyster investigators, viz., that some—by no means

[1] Our thanks are especially due to Professor Sherrington, Dr. C. Kohn, Dr. Abram, Mr. Cole, and Mr. Scott. We are indebted to Mr. C. Petrie, Liverpool, and Mr. Rupert Vallentin, Falmouth, for help in obtaining special kinds of oysters.

all—of our oysters and mussels are grown or kept under most insanitary conditions, and so may, when taken as food, without the necessary precautions, from unhealthy localities, cause disease or poisoning. The conclusions on the public health question are entirely in accord with what we (Boyce and Herdman) recommended in a former report (Ipswich, 1895) as the two requisite sanitary measures, namely, first, the inspection of all grounds upon which shellfish are grown or bedded, so as to ensure their practical freedom from sewage; and, secondly, the use, when necessary, of what the French call 'dégorgeoirs'—tanks of clean water in which the oysters should be placed for a short time before they are sent to the consumer.

Copper in Oysters.

There are two other points in the Medical Officer's Report to which we must allude. The first is that Dr. Bulstrode's report corroborates our account of the pale green disease which we have discussed in our previous papers, and which we refer to more fully below. He has independently met with a condition in oysters from the South Coast of England which is clearly the diseased condition we had described. This is the more important as Dr. Carazzi in the paper referred to above seems inclined to doubt our account of the pale green disease. The second point is that Dr. Thorpe, who examined some green oysters obtained by Dr. Bulstrode at Falmouth, found that they contained a notable amount of copper. This observation has raised once more the question, which was by many considered settled, as to whether large amounts of copper might be taken up by the oyster, and as to whether any of the green forms of oyster owe their colour to copper.

We have alluded in former reports [1] to the great difference of opinion that has existed in the past as to the green colour of certain oysters, and there can be no doubt that that difference of opinion has been largely due to the fact that the observers worked with different kinds of oysters. Some investigated Marennes oysters (*O. edulis*) and found that with dark blue-green gills they were in a perfectly healthy state, that they contained very little copper, and that some iron was present in the pigment. In all that they were perfectly correct; but that does not prove that the pale green American oyster (*O. virginica*) is also in a healthy state, and that its green colour is due to iron and not copper. If there is one thing more than another which this investigation has taught us, it is caution in drawing general conclusions from what is found in one oyster or one brand of oysters. At an early period of the investigation we were inclined to agree with some previous investigators that copper, though present in small quantity in all oysters, had nothing to do with the green colour; but now we have to definitely announce that we find copper in considerable quantity in the green American oysters, that the copper reaction coincides histologically with the green granular leucocytes, and that consequently the copper may be regarded as the cause of the green colour.

Professor Bizio records that he found (in 1835 to 1845) copper in oysters at Venice; and he suggests that the colour of the Marennes oyster is due to a compound of copper. Subsequent work upon Marennes oysters, in which little or no copper was found, may have seemed to throw

[1] *Brit. Assoc. Rep.*, 1896, p. 668; and *Report Lancashire Sea-fisheries Laboratory* for 1895 and 1896.

discredit on Bizio's observation; but we think it very possible, in the light of our recent experience, that Bizio was dealing with the same copper-bearing green pigment that we have met with.

From numerous analyses that have been made for us by Dr. C. Kohn, it is pretty certain that about 0·006 grain (0·4 mgrme.) of copper is the amount that is normally present in the healthy oyster; and this copper is usually supposed to be located in the hæmocyanin, which, as Fredericq and others have shown, is a constituent of the blood of many crustaceans and molluscs. The amount of copper, however, that we have lately found in green oysters is far in excess of what can be accounted for as due to the hæmocyanin.

Out of 120 American oysters opened at one time, we picked the six greenest and the six whitest. Dr. Kohn analysed these for us and found that the six green ones contained 3·7 times as much copper as the white. This shows that there is an absolute increase in the amount of copper present in the body, and not merely a redisposition, such as the concentration of the copper of the hæmocyanin in certain leucocytes.

Further, Dr. Kohn finds that the greenest parts of an oyster, if snipped out and analysed, contain, in a ratio corresponding to that stated above for whole oysters, more copper than the corresponding parts of a white oyster. These experiments, and the histological reactions described below, demonstrate the coincidence of the copper distribution with the green colour.

Seat of the Green Colour.

It may be well that we should state again the method of occurrence and the histological distribution of the green colouring matter. In the American oyster (*O. virginica*) re-bedded on the English coast, a well-marked pale chalky green colouration is frequently observed, especially in autumn. This colour, in its appearance and distribution, is unlike that seen in the gills of the Marennes oyster. It may occur in patches on the mantle, but more frequently it is confined to the vessels and heart; in some cases, owing to the universal injection of the vessels, the entire oyster has a greenish tinge. Microscopic examination shows that the green colour is due to leucocytes, which are coarsely granular. The leucocytes are amœboid and tend to collect in masses. The oysters in which this massing of green leucocytes occurs do not appear to us as healthy as those which are colourless. They are frequently thin, with the liver shrunken, but we were unable to find evidence of any parasitic or other irritative cause of the disease, either by staining or cultivation. Examination of considerable numbers of the English native (*O. edulis*) shows that the green colouration is occasionally encountered in that form, and that it is due to the same cause, but it is by no means so frequent as in the American species.

Investigation of the Pigment.

The following are our details of the histo-chemical investigation of the pigment. The green pigment is insoluble in boiling alcohol, ether, chloroform, xylol, and other fat solvents; it is soluble in dilute acids and alkalis. The addition of potassic ferrocyanide to sections containing the green colouring matter, or to the leucocytes themselves, gives a red reaction, indicating the presence of copper; but the reaction can be

most readily obtained by the addition of a small quantity of ·5 per cent. hydrochloric acid to the potassic ferrocyanide. Ammonium-hydrogen sulphide gives also an immediate reaction with the green pigment. Ammonia strikes a beautiful blue wherever there is green. It was then found that pure hæmatoxylin is an extremely delicate test, giving an immediate blue reaction in exceedingly dilute solution. Previous treatment of the green colouring matter by 3 per cent. nitric acid in alcohol prevented these reactions, and subsequent treatment with acidulated potassic ferrocyanide resulted in a very faint general prussian blue colouration of the tissue generally. We concluded that there was *no inorganic iron* present in the leucocytes, that the leucocytes which form the green patches contain a considerable quantity of copper, and that, just as in the case of iron, as shown by Professor Macallum,[1] pure hæmatoxylin is a most delicate test, but that great care must be taken to ascertain by other reagents which of the metals is present. Very numerous tests were made with the blood obtained from white oysters, and micro-chemical reactions revealed in some instances faint traces of copper. Hæmocyanin has been described in the blood of molluscs and apparently in the blood of the oyster. We have examined numerous samples of blood taken from the white oyster, but have failed to get any blue colouration on exposure to air. In the green oysters a very faint blue colour has been noticed in some cases on exposing the blood to air.

Cause of the Pigmentation.

There can be no doubt that Ryder,[2] in America, about 1880, investigated the same kind of green oyster with which we are dealing. He showed that the green colouring matter was taken up by the amœboid blood-cells, and that these wandering cells containing the pigment were to be found in the heart, in some of the blood-vessels, and in aggregations in 'cysts' under the surface epithelium of the body. He describes the colour (in the ventricle) as a 'delicate pea-green,' and states that it is not chlorophyll nor diatomine; he suggests that it may be phycocyanin or some allied substance. We have now shown that it is due to a copper compound.

We consider that Ryder came nearer to what we now consider to be the truth than any previous investigator has done. He was trying to show that the colour was derived from the food. Carazzi has recently suggested that the colour (this, it must be remembered, is in the Marennes oyster), due to iron, is derived from the bottom on which the oyster is lying. We have tried numerous experiments in feeding oysters on iron and copper salts, both soluble and insoluble, of various strengths, and also in keeping oysters on a bottom of iron or copper salts—including rusty iron, old copper, and copper filings—but in none of these experiments (the full details of which we shall publish later) have we got sufficiently consistent and continuous results to enable us to determine whether or not the animal obtains its copper from the contents of the alimentary canal or from the water through the surface of the body. These experiments and observations are still being carried on.

[1] *Quarterly Journal of Microscopical Science*, 1896; and *Brit. Assoc. Rep.*, 1896, p. 973.

[2] U.S. Fish Commission. Reports and Bulletins from 1882 to 1884.

We may add that the green oysters containing copper are found in some localities where there can be no question of copper mines or old copper from ships' bottoms. We venture to suggest that the pigmentation may be due to a disturbed metabolism whereby the normal copper of the body becomes stored up in certain cells.

We desire to continue this work. Our investigation is drawing to a conclusion, but there are still some points we hope to settle, such as the origin of the copper and the conditions determining its deposition. The colouring matter in the other kinds of green oysters also requires reinvestigation. We desire, then, that the Committee should be reappointed for one year more, with the addition of Dr. Kohn, who has rendered us valuable service on the chemical side, and with a grant to meet the expenses of the investigation.

Index Animalium.—Report of a Committee, consisting of Sir W. H. FLOWER (*Chairman*), Mr. P. L. SCLATER, Dr. H. WOODWARD, Rev. T. R. R. STEBBING, Mr. R. MACLACHLAN, *and* Mr. F. A. BATHER (*Secretary*), *appointed to superintend the Compilation of an Index Animalium.*

THE object of this Committee is to prepare, and ultimately to publish, an index to every name, whether valid or invalid, that has ever been applied as the generic or specific denomination of an animal, recent or fossil. The work of compiling the Index is carried on by Mr. C. Davies Sherborn at the British Museum (Natural History).

The Committee has decided to deal first with the names occurring in literature published between the years 1758 and 1800 inclusive, since this section of the literature is the most important for questions of priority. Within these limits Mr. Sherborn has during the past year prepared a list of the literature to be searched.

Since the last Report was drawn up 982 volumes and tracts have been indexed, and about 10,000 species listed. In addition Mr. Sherborn has prepared a separate index of the names of animals in the tenth and twelfth editions of Linnæus's 'Systema Naturæ,' since it was considered by the Committee that the publication of this would be a useful preliminary step of much value to naturalists.

The Committee begs to remind zoologists that the Index, in the form of a card catalogue, now containing about 140,000 references, can be referred to in the library of the Geological Department of the British Museum (Natural History) any week day between 10 A.M. and 4 P.M.

A detailed account of the methods and progress of the work was published in the 'Proceedings of the Zoological Society' for 1896, pp. 610–614, and was reprinted in the 'Geological Magazine' (n.s., Dec. iv., vol. iii. pp. 557–561, Dec. 1896). A notice of this and an appeal for the support of zoologists was published in 'Natural Science' for June 1897 (vol. x. pp. 370–371).

The value of this work to zoologists (including palæontologists) and the satisfactory progress that the grant of 100*l.* by the Association has rendered possible justify the Committee in recommending its reappointment, with the addition of Mr. W. E. Hoyle, and in asking for a renewal of the grant.

African Lake Fauna.—Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Dr. JOHN MURRAY, Professor E. RAY LANKESTER, Professor W. A. HERDMAN, *and* Professor G. B. HOWES (*Secretary*).

MR. J. E. S. MOORE, A.R.C.S., London, left England on September 7, 1895, and returned to Europe on January 1, 1897.

The primary object of his expedition was the collection, by means of dredging, tow-netting, and other resources, of material for the adequate working out of the structure, and, as far as possible, the development, of the singular fresh-water Medusa (*Limnocnida tanganyikæ*), and some other remarkable animal forms which, from their shells brought home by travellers, were known to inhabit Lake Tanganyika, and to present a combination of characters unlike that of any other fresh-water stock. Incidentally, the faunas of Lakes Shirwa, Kela, and Nyassa were as far as possible studied; and in this way much light has been thrown on the geographical distribution of the fauna of the great African lakes. It has been ascertained that Tanganyika contains at least two distinct faunas—one which is more or less fully represented in all the great African lakes, and another peculiar to Tanganyika itself. The latter embraces the Medusa, some of the fresh-water fishes yet to be determined, some new species of Crabs and Prawns, a deep-water Sponge, and members of some eight or nine genera of Gastropods. Some of the latter are already known from their shells (such as *Typhobia*, *Lithoglyphus limnotrochus*, and *Paramelania*), but there are others which have yet to be described. All these animals, like the Medusa, exhibit marked marine affinities, but they cannot be directly associated with any living oceanic forms; and it is suggested they may represent the remains of a special fauna which has persisted in the lake for a vast period.

Observations were also made upon the Protozoa of Lake Tanganyika, with the result that there were discovered apparently new species of *Condylostoma* and *Peridinium*, both of which are widely distributed over the surface of the lake.

A number of topographical observations were made, and rock specimens were collected which will add to our knowledge of the geology of the districts visited. Besides this, representatives of classes and orders of animals other than those referred to above were collected. Mr. Moore is at present working out the collections at the Royal College of Science, South Kensington, and the full results will be published in a series of papers to be communicated to the Royal and Zoological Societies, and in the 'Quarterly Journal of Microscopical Science.'

The following is a diary of Mr. Moore's movements while in Africa:—

Arrived at Capetown on September 21, 1895, and at Durban on September 28. Left Durban on October 18 (having been detained by the loss of a steamer), and arrived at Chinde on November 2. Left Chinde on November 4, and arrived at Blantyre, *via* the Zambesi and Shiré Rivers, on November 27. Being detained by the war in progress at the north-east end of Nyassa, Mr. Moore left Blantyre for Zomba on December 23, and after an interview with Sir Harry Johnston, to whom Mr.

Moore expresses his special indebtedness for assistance and advice, he left Zomba again for Blantyre on December 26. On January 1, 1896, he left Blantyre for Mtope, on the Upper Shiré River, and proceeded thence by boat to Fort Liwonde. Proceeding up the Shiré River to Fort Johnston, which was reached on January 8, he, through the kindness of Sir Harry Johnston, was enabled to embark his men and goods on the gunboat 'Pioneer,' on which he proceeded up Lake Nyassa, arriving at Karonga on February 28. There a further delay occurred, owing to the necessity for collecting men for the march across the plateau. On reaching Mweinwanda's village, 40 miles N.W. of Nyassa, delay arose from fever. On recovery, Mr. Moore proceeded to Fwambo, which was reached on March 16. Leaving that place on the 17th, a day's journey brought him to the Chartered Company's new station at Fort Abercorn, from which, after a long day's march, the south end of Tanganyika was reached on March 19. The remainder of Mr. Moore's time was passed on or near the shores of Lake Tanganyika, in visiting places favourable for dredging, and in making observations on the topography of the district. Several excursions were undertaken into the surrounding country, east and west, especially with a view to the study of the remarkable geology of the Loofu Valley, the river of which reaches Tanganyika through a precipitous gorge, near the south end of Cameron Bay. Mr. Moore left Kituta on September 7, 1896, and returned by the same route as he went up, reaching Europe on New Year's Day, 1897.

Zoology and Botany of the West India Islands.—Tenth Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Mr. GEORGE MURRAY (*Secretary*), Mr. W. CARRUTHERS, Dr. A. C. L. GÜNTHER, Dr. D. SHARP, Mr. F. DU CANE GODMAN, Professor A. NEWTON, *and* Sir GEORGE HAMPSON, *on the Present State of our Knowledge of the Zoology and Botany of the West India Islands, and on taking Steps to investigate ascertained Deficiencies in the Fauna and Flora.*

THIS Committee was appointed in 1887, and has been reapppointed each year until the present time.

During the past year the following papers have been published :—

1. On the Diptera of St. Vincent (West Indies), by Professor S. W. Williston ('Trans. Ent. Soc.,' London, 1896, pp. 253–446, plates 8–14).

2. On the Heteromerous Coleoptera of St. Vincent, Grenada, and the Grenadines, by G. C. Champion ('Trans. Ent. Soc.,' London, 1896, 54 pp. and 1 plate).

3. On West Indian terrestrial Isopod Crustaceans, by A. Dollfus ('Proc. Zool. Soc.,' London, 1896, pp. 388–400).

The Committee hope during the ensuing year to complete their undertakings. All the plants collected have either been published or are now in the hands of experts. There remain a few groups of Insects not yet undertaken, and the Committee request reappointment, without a grant, to enable them to finish their work, the following to be members : Dr. Sclater (Chairman), Mr. G. Murray (Secretary), Mr. F. Du Cane Godman, Dr. Sharp, and Sir George Hampson.

Investigations made at the Marine Biological Laboratory, Plymouth.—Report of the Committee, consisting of Mr. G. C. BOURNE (*Chairman*), Professor E. RAY LANKESTER (*Secretary*), Professor S. H. VINES, Mr. A. SEDGWICK, *and* Professor W. F. R. WELDON, *appointed to enable* Mr. WALTER GARSTANG *to occupy a table at the laboratory of the Marine Biological Association at Plymouth for an experimental investigation as to the extent and character of selection occurring among certain eels and fishes, and to cover the cost of certain apparatus.*

THE Committee have received the following report from Mr. Garstang:—

'I occupied the British Association table at the Plymouth Laboratory during the last Easter vacation, and found the large experimental tank, which I had arranged to be built, ready for work. A number of preliminary experiments upon the relations as enemies and prey between certain small shore-crabs and shallow-water fishes were made during my tenure of the table, and showed the feasibility of studying the process of selection under the semi-natural conditions of a specially constructed aquarium. A large number of coloured figures have been made under my direction by Miss Willis, to illustrate the course and results of the experiments.

'My appointment, in May last, as naturalist at the Plymouth Laboratory compelled me, however, to resign my occupation of the British Association table, and has temporarily interrupted the progress of the work. This, however, will be resumed at an early date, and I hope to be in a position to lay the results of the inquiry before the Association at the Bristol meeting.'

The Position of Geography in the Educational System of the Country.—Report of the Committee, consisting of Mr. H. J. MACKINDER (*Chairman*), Mr. A. J. HERBERTSON (*Secretary*), Dr. J. SCOTT KELTIE, Dr. H. R. MILL, Mr. E. G. RAVENSTEIN, *and* Mr. ELI SOWERBUTTS. (*Prepared by the Secretary.*)

THE holding of the Sixth International Geographical Congress in London, in 1895, forcibly drew attention to the position of geography in our educational system. Sir Clements Markham, in his eloquent presidential address, spoke most impressively of the inadequate manner in which geography was treated in our country, and urged the need of altering this. In the discussion on geographical education, the British members emphasised the statements of the President, and a committee was appointed to draw up a resolution on the subject of geographical education. The Committee decided that any resolution proposed for adoption by an International Congress should not reflect on the affairs of any country, but must deal with general considerations applicable to all countries, and accordingly the Committee proposed and the Congress passed the following resolution:—

'The attention of this International Congress having been drawn by the British members to the educational efforts being made by the British Geographical Societies, the Congress desires to express its hearty sympathy

with such efforts, and to place on record its opinion that in every country provision should be made for higher education in geography, either in the universities or otherwise.'

At the meeting of the British Association at Ipswich in 1895, the president of the Geographical Section, Mr. H. J. Mackinder, Reader in Geography at Oxford, discussed the question of geographical education in his address—contrasting British and German conditions—and pointed out the deficiencies as well as the merits of British geographers and teachers of geography. Ultimately the Committee responsible for this report was appointed to inquire into the position of geography in the educational system of the country.

No report on the position of geography in our educational system can be adequate which does not take into account Dr. Scott Keltie's well-known Report to the Council of the Royal Geographical Society published as a supplementary paper of the Royal Geographical Society in 1885 (vol. i., Part IV.). It has not been thought necessary to discuss fully many matters dealt with in detail in Dr. Keltie's report, to which readers are referred.

Unfortunately the Committee, owing to there being no funds at their disposal, have not been able to undertake a personal inspection of various educational institutions at home and abroad, such as that carried out by Dr. Keltie. They have had to rely on their individual experiences as teachers and examiners in geography, on a comparison of documents relating to geographical education published in this and other countries, and on numerous correspondents, both at home and abroad, to whom they now tender their best thanks for full and courteous replies to numerous questions. In addition to those whose communications are printed in the Appendix are Professors Kan of Amsterdam, Malavialle of Montpellier, Neumann of Freiburg i. B., Penck of Vienna, Elisée Reclus of Brussels.

There are obvious disadvantages about this method. Programmes reveal the intelligence of their compilers but not the efficiency of those who follow them in teaching. A good teacher can succeed in obtaining excellent results with a poor syllabus, while an inefficient one may fail to educate even when he follows a well-planned course.

Examination papers show the conceptions of geography held by the examiners, yet the teaching may be of a much better or much worse type than the nature of the examiner's questions would indicate. The personal experience of members of the Committee as examiners has been of great service in testing how far sound geographical instruction is given in different institutions. The previous training of their own pupils is also a valuable index of the work done in geography in our schools.

1. *ELEMENTARY EDUCATION.*

A. ELEMENTARY SCHOOLS.

Day Schools.—In Dr. Keltie's report in 1885, it is stated that 'Geography has been made compulsory, and must be taught according to a generally prescribed method which, if carried out everywhere with intelligence and enthusiasm, would be nearly all that could be desired.'

Geography unfortunately is now only an optional subject in the elementary schools in Great Britain. It may be one of the two possible class subjects chosen from a number. Geography is taught in two-thirds

of the schools in England and Wales, and about 95 per cent. of those in Scotland. In England and Wales in 1894–95, 15,250 schools took geography out of 23,027; in 1895–96, 15,702 out of 23,075. In Scotland in 1894–95, 2,990 schools out of 3,063; in 1895–96, 3,018 out of 3,094 chose geography as a class subject.

The syllabuses of geography differ in the two countries. (See Appendices I. and III.)

The English syllabus has not been altered materially since 1885; but the pupils no longer need to learn the geography of extra-European countries, except British Possessions and the United States of America.

Two alternative programmes are permitted by the Education Department for England and Wales.

Course A differs little from the ordinary programme, but is better in so far as it emphasises the study of climate and of industrial products.

Course B has nothing about the world as a whole, but home geography is taught in Standard II., and the geography of Asia and Africa in Standard VII.

A fourth programme is printed for a combined course in history and geography. Geography is taught only in the first four standards—in I., II., and III., the syllabus is the same as in the normal course, but the geography of Europe and Canada and Australia is prescribed for Standard IV. A fifth scheme permits the teaching of geography in Standard IV. and higher standards, when other class subjects have been chosen in lower standards.

The Scottish syllabus does not differ greatly from the English ones, but includes the 'Geography of the World in Outline.' Only one syllabus is given in the Scottish Code.

The syllabus for Irish National Schools (Appendix IV.) lays more stress on maps. It is taught in all but the two lowest classes. Physical Geography forms a subject in the science programmes of the fifth and higher classes, and may be one of two extra subjects for which results payments can be claimed.

The chief fault of these programmes is that while they permit an extension of topographical information they make little provision for an increase of geographical power. In them the more advanced classes in geography learn about distant lands, but do not necessarily progress in their knowledge of geographical principles. This is more important than an accumulation of additional facts, and in many of Her Majesty's Inspectors' reports the lack of this grasp of principles is deplored.

The reports of Her Majesty's Inspectors of Schools in England and Wales lead us to infer that a gradual, if slow, amelioration is going on in elementary school teaching of geography, but that, while 'the ordinary general facts in the text-books or manuals are generally well got up,' 'the information is often too bookish and not sufficiently practical,' and that 'the want of definite scientific training in some teachers often leads to imperfect or erroneous instruction in the important physical aspects of the subject.'

In Scotland Dr. Ogilvie reports the 'schools in which mere strings of names and disjointed facts are glibly repeated are getting fewer and further between.' The Scottish inspectors also point out, however, that while sufficient attention is paid to topography, the other more educational and more practical branches of geography are often badly treated.

When the geography syllabuses for foreign elementary schools are

compared with those of this country, it is found that many recognise the need for more advanced geographical teaching in the higher forms.[1]

Evening Continuation Schools.—Geography is taught in many evening continuation schools, and is reported to be an attractive subject. The syllabus is given in Appendix VIII. The subject of elementary physiography is also taught, but it contains very little physical geography.

B. THE TRAINING OF ELEMENTARY SCHOOL TEACHERS IN GEOGRAPHY.

The successful teaching of geography in our schools depends not so much on sufficient syllabuses or efficient inspection as on properly trained and enthusiastic teachers.

Primary school teachers have opportunities for studying geography, after passing the standards (1) during their apprenticeship at school, and (2) in the training colleges.

England and Wales.—Pupil teachers revise the geography of the world in greater detail than in the school classes (Appendices IX. and X.). This is the preliminary work necessary before attempting the training college entrance examination, known as the Queen's Scholarship examination, which is on a restricted syllabus.

In England and Wales this teaching is not of a very high standard, judging from the examiners' reports. 'The answers to the general questions showed that candidates had seldom been taught to group their information upon any principle or to lay stress on the connection between facts.' That is to say, the candidates seldom know any geography.

Yet there are great inducements held out to those who know enough geography to gain distinction in this examination. The best candidates are rewarded by being 'released from the obligation to take up the subject again in the training colleges, and are also exempt from it in the certificate examinations.'

The proportion of students who take geography in the resident training colleges is very large, but this may be due to the enlightened views of the principals of these colleges, who may realise the need for thorough training in geography of all elementary school teachers, most of whom will be called upon to teach it.

The following table shows the numbers taking geography in their certificate examinations.

Year	Total of First Year Male Students	Number taking Geography	Total First Year Female Students	Number taking Geography	Total Second Year Male Students	Number taking Geography	Total Second Year Female Students	Number taking Geography
1894	704	663	1042	1034	710	22	1002	878
1895	686	668	1046	1037	709	29	1051	1012

In some of the Day Training Colleges the majority of those who have gained distinction in the Queen's Scholarship examination do not take up geography again, but this may, perhaps, be altered, by the new regulations admitting geography as an optional subject for the first degree examination in the colleges which form Victoria University (Appendix XXXIX.).

[1] See Appendices V. to VII., giving programmes in Austria, Belgium and France. See also Professor Levasseur's account of French programmes in the *Report of the Sixth International Geographical Congress, London*, 1895.

The syllabus for the certificate examination varies from year to year, but the same paper is set for first and second year students. (See Appendix XI.)

The inspectors' reports show that the quality of the work depends largely on the quality of the teaching in the training colleges.

In the certificate examinations the subject of physiography may also be taken. The syllabus followed is that of the Science and Art Department, which makes physiography equivalent to elementary physical science, and therefore a most useful preparation for physical geography, but by no means equivalent to it, and not to be confused with it.

Scotland.—In Scotland the Code for pupil teachers is much the same as that in England, but the syllabus of the Queen's Scholarship examination is more general. (See Appendices XII. and XIII.)

The Scottish inspectors report that the 'attention given to climate and productions is inadequate,' and that the text-book apparently is still the only geography book of many candidates.

The standard of this examination is much higher than that in England and Wales, for the Royal Geographical Society continues to give prizes and certificates to the best candidates in Scotland, but not in England and Wales.

Perhaps this explains why the attention given to geography in the Scottish training colleges is so perfunctory, and why a smaller percentage of candidates take geography in their certificate examinations in Scotland than in England, for the rule excusing the better geographical students from a further study of geography is in force in both countries.

The Committee have been informed that the pupils in most Scottish Training Colleges, whether they study geography necessarily or voluntarily, do so by themselves. Their work, however, is prescribed by a master, who sets an examination paper at intervals, and afterwards criticises the work done by the students in these examinations.

In the Scottish Code the subject is called 'Geography and Physiography,' and physiography is regularly taught in the training colleges. This is obviously inadequate geographical training. The syllabus is given in Appendix XIV.

Ireland.—In Ireland monitors have to study additional geography to that of the class in which they are enrolled (Appendix XV.). The entrance examination to the Training Colleges contains little or no physical geography. Geography must be studied during the first year at the Training College, but is not a necessary subject of the second year's course for those who make 60 per cent. in the examination in geography at the end of the first year (Appendix XVI.).

In Ireland, even the Inspectors and their assistants must pass an examination in geography (Appendices XVII. and XVIII.).

Other Countries.—In foreign lands teachers are usually more systematically trained in geography, and programmes of their course of study are given in Appendices XIX. to XXI.

2. *SECONDARY EDUCATION.*

A. SECONDARY SCHOOLS.[1]

England.—In England we do not possess the guides to the position of geography in secondary schools which could be followed in the case of primary schools. Secondary education is still in an unorganised condition,

[1] The Public Schools are included in the term Secondary Schools.

and every variety of geographical education can be met with, for geography is actually not taught in some schools, while in a very few cases it may be looked upon as the central subject of the curriculum.

Several members of the Committee have had considerable personal experience in conducting examinations in geography for secondary school pupils. The Geographical Association, founded by secondary schoolmasters interested in the teaching of geography, has been good enough to place at the Committee's disposal the correspondence which was received in a recent enquiry made by them concerning geography in secondary schools. Selections from this correspondence show what different treatment is meted out to geography in different schools. The brief and pointed letter of one headmaster may be quoted here: 'Dear Sir,—We have no army candidates and I have no interest in geography, yours truly, ——,' and contrasted with that of another master, who wrote: 'Personally, I found all my teaching, historic, literary, &c., on geography, and the results are most encouraging.'

It is impossible, therefore, to form an accurate account of the position of geography in secondary schools in England except by personal inspection. In a few it is adequately recognised and admirably taught, in some it is completely neglected, in the majority it is given to a master who has had no training and often has no interest in the subject.

As there is no authoritative body dealing with such schools in England, the Geographical Association consider that the best way to improve the position and teaching of geography in the existing conditions, is to improve its position and quality in public examinations. Accordingly a number of suggestions have been submitted to about three hundred secondary schools for criticism, but only one-third have taken any notice of them. (Appendix XXIIA.)

These replies have furnished the basis of a series of recommendations which have been sent to the examining bodies affecting secondary schools. (Appendix XXIIB.)

The examinations affecting secondary schools are those admitting to the universities, the professional colleges, or different branches of the national service—military, naval, civil—the University Local Examinations and the Examinations of the College of Preceptors and the Society of Arts.

In some of the university and college entrance examinations geography has a place in the examination paper in English, but in most cases it is a very unimportant part of it. (See Appendix XXIII.)

Geography has a prominent place in many of the examinations conducted by the Civil Service Commissioners, but in some of the higher examinations it should be awarded more marks; for instance in the Army Entrance examination, as is mentioned in the memorial of the Geographical Association, which points out, however, that the style of questions set in these examinations is improving.

In the University Local Examinations 'geography is a subject both for the Junior and the Senior Certificate, and there has recently been established a more ambitious scheme for the higher certificate.'

The Oxford and Cambridge Joint Board conducts the examinations of schools such as the Public Schools and the Girls' High Schools. 'In the Higher Certificate Examination, Geography only comes in as incidental to the examination in History.' Physical Geography and Elementary Geology forms, however, an optional subject in this examination. Geo-

graphy may be taken as an independent subject of examination for the Junior Certificate, but is not compulsory. (See Appendix XXIV.)

The College of Preceptors conducts examinations in schools either on a syllabus drawn up by the college or by the school. In the former case no geography is required in the first and second grades, but for the third and fourth grades a syllabus is given. (See Appendix XXVA.)

Schools may be examined in extra subjects, of which physical geography may be one or the geography of two continents another.

It is an optional subject in the professional preliminary examination conducted by the College of Preceptors (Appendix XXVc.); but no commercial geography is required for the commercial certificate.

In the certificate examinations of the College of Preceptors candidates, in addition to other subjects, must choose one of the three—English, History and Geography; but all may be taken. The outline of requirements seems to indicate that topographical and political geography is all that is necessary; except for first-class certificates, where 'Geography, Political, Physical and Mathematical,' is the title employed.

The Society of Arts conducts examinations in geography which are taken advantage of by many schools.

Wales.—Mr. F. W. Phillips, Headmaster of the Newport Intermediate and Technical School, writes: 'Geography is an obligatory subject in all intermediate schools, to the extent that it must be introduced into the curriculum somewhere or another. This does not necessarily imply that every form in the school will take it, for the letter of the regulation, though perhaps not the spirit, would be complied with if but one form did so. Generally speaking, it might be taken for granted that it will be attended to in the lower school in all cases.

'Its fate in the upper school will depend upon:—

'(*a*) The extent to which the different departments of the upper school are developed;

'(*b*) The ultimate attitude of the Universities towards the subject.

'The development of departments will vary with the size of the school. The final development would give at least three strong departments, classical, science and commercial, each of which would be represented by at least one form, called, say, the Classical Sixth, the Science Sixth, and the Modern Sixth. If the school be very strong there might be three corresponding fifth forms. But, for the moment, take the three Sixths into consideration. Will they do geography?

'The Modern Sixth. Yes, certainly, a course of commercial geography.

'The Science Sixth. Hardly, unless there were some distinct encouragement for scientific geography in the chief science scholarships.

'The Classical Sixth. Not unless the subject be made a possible one for university matriculation, or unless it were allied with history in scholarship examination.'

Scotland.—Secondary education is somewhat better organised in Scotland than in England. The academies and high schools prepare their advanced pupils for the leaving certificate of the Scottish Education Department or for the preliminary examinations of the Scottish Universities.

In the examinations both of the Education Department and of the Universities geography occupies a subordinate place in the examination in English.

The position of the Scottish Education Department has been clearly defined as follows :—

'With regard to history and geography, my Lords have little to add to the remarks which they have made in previous years. These subjects enter largely into the curriculum of many schools; they are required by many of the bodies by whom the leaving certificate is recognised, and my Lords are unwilling to do anything which would discourage the continuance of such instruction. They endeavour to give a wide option in the questions set, and to afford opportunity to all who have not entirely neglected the subjects to show a knowledge of them in some branch or other. More than this they have not demanded, and do not propose to demand, as a necessary condition of a pass, but more extensive knowledge will receive ample recognition.' [1]

Candidates must answer one question, and a second question may be attempted, if desired, in the lower grade examination, while two questions must be answered, and three may be attempted, in the higher grade examination. Full marks can be obtained for honours grade certificates without any question in geography being answered. (Appendix XXVII.)

'The geography is in general faulty, and there is rarely evidence that this subject is taught in any methodical way, or presented to the pupils in such a manner as to make a vivid impression upon them.' [2]

In the preliminary examinations for the Scottish Universities two questions in geography have to be answered in one of the papers in English for Arts and Science students, but only one question is compulsory for medical students. (Appendix XXVI.)

In the Edinburgh University Local Examinations elementary history and geography form one compulsory subject in the preliminary, geography and physical geography two optional subjects in the junior, geography an optional subject in the senior, and commercial history and geography a compulsory subject in the commercial certificate examinations.

Ireland.—Geography forms part of the paper set in the examinations of Irish intermediate education. The reports of the examiners in recent years indicate that some knowledge of topography is taught, especially of the British Isles, but questions on physical geography are rarely well answered. (See Appendix XXVIII.)

Geography is also a part of the entrance and some Scholarship examinations of Trinity College, Dublin (Appendix XXIX.); and one question is usually set in this subject in the entrance examinations of the Royal University (Appendix XXX.).

Other Countries.—In Dr. Keltie's report detailed accounts are given of the position of geography in the secondary education system of foreign countries. Since then some of the programmes have been modified, some for the better, others for the worse.

In France geography is taught in every class of the Lycées, and the new programmes are given in Appendix XXXII. Professor Levasseur's paper, read to the Sixth International Geographical Congress, gives a useful comparison of old and new programmes.

In Prussia geographers complain of a retrograde movement in the last

[1] *Report for* 1895, *by* HENRY CRAIK, Esq., C.B., on the 'Inspection of Higher Schools and the Examinations for Leaving Certificates,' p. 192.

[2] *Ib.* p. 182.

programme, especially in placing political before physical geography; and the German philologists and schoolmasters have passed a resolution demanding that geography should be taught in every form or class of the Gymnasium. Other German States have not followed the Prussian authorities in this.

In the United States of America a committee of ten appointed by the National Education Association to enquire into secondary school studies have recommended that physical geography should receive three hours' teaching per week in the first year of secondary schools (age 14–15). In the fourth year, in all save the classical forms, physiography, in the American sense of the word (*i.e.* geomorphology), is suggested as an alternative with geology for three hours' work per week. The committee which advised the committee of ten about geographical education have unfortunately neglected advanced geography, except in its physiographic or geomorphological and meteorological aspects.

B. TRAINING OF SECONDARY SCHOOL TEACHERS IN GEOGRAPHY.

United Kingdom.—Our secondary schools need trained teachers in geography far more than elaborate programmes. If the training of elementary school teachers leaves much to be desired, it is due not so much to lack of organisation as to deficiencies in the ideals of the responsible authorities. The secondary school master and mistress have had very little chance hitherto of learning any geography, except privately or by going to foreign institutions. The most important educational work in the immediate future is the provision of proper geographical training for secondary school teachers, a training which will enable them to read maps and think geographically, and not merely to read and reproduce the words of a text-book, to regard geography as an interpretation of a living world and not a catalogue of positions or definitions of directions.

Most secondary school teachers in this country and abroad are trained in the universities. But only two universities in the United Kingdom recognise geography as an optional subject for the ordinary degree, while a third has made it a minor subject necessary for a degree in History. In none has it the position it occupies in the majority of even the smaller Continental universities. There are facilities for learning some geography at Oxford and Cambridge, and, to a slight extent, at the University Colleges of England and Wales, as is noted in the next section of this report. But it is to be regretted that so few masters and mistresses in our secondary schools have been trained in modern geographical ideas and methods.

Other Countries—The German geographers, at their last biennial congress at Jena in 1897, protest most strenuously against the deterioration of geographical teaching in Prussia in recent years, owing to the new regulations which permit masters untrained in geography to teach it—the normal condition in the United Kingdom. On this matter Dr. H. Wagner, of Göttingen, says in his report of the proceedings of this Congress in the 'Scottish Geographical Magazine' (June 1897): 'Besides the fact that the weekly lessons in geography in the upper classes have been curtailed, a greater evil lies in the practice of the heads of educational institutions to intrust the teaching of geography to masters who have never studied the subject at the university, or submitted their knowledge of this branch of learning to the test of an examination. Dr. Fischer gave ample proofs of this from

statistics relating to the numerous schools of Berlin. Being convinced that the higher school boards are not fully acquainted with this untoward state of matters, or do not properly realise its consequences, the Geographical Congress resolved that Dr. Fischer's paper should be sent to all the high schools of Germany.' But it must be borne in mind, as Dr. H. R. Mill points out in his report ('Geographical Journal,' June 1897), that 'this does not mean that they [the teachers uncertificated in geography] are not without a competent general knowledge of the subject, probably better in all cases than that possessed by even the more intelligent English teachers.'

The conditions have not gone backwards in all German States. The syllabus of geographical studies necessary to teach geography in the Gymnasia of Austria and Baden are given in Appendices XXXIII. and XXXIV.

In Belgium the teacher of geography in an Athénée is a doctor in history and geography (Appendix XXXV.).

In the French Lycées, too, the teacher is usually an agrégé in history and geography. The syllabus for the agrégation for 1896 is quoted in Appendix XXXVI.

3. *HIGHER EDUCATION.*

Universities and University Colleges.

England and Wales.—In the United Kingdom there is one professor and two lecturers in geography. The professorship is in King's College, London. There has been a reader in geography at Oxford for ten years, and a lecturer at Cambridge for eight years. In the Victoria University geography is taught by the geologists and economists, while for five years an independent lectureship in geography existed at the Owens College, which was merged in that of political economy owing to lack of funds, and not lack of interest. In the other university colleges of England and Wales geography is taught to training college students who have not done well in that subject in the Queen's Scholarship examination, usually by the Master of Method, and in Birmingham by the Professor of Geology.

In Cambridge geography is now a compulsory part of the Historical Tripos (Appendix XXXVII.).

After ten years' experience of geographical teaching Oxford has resolved to make the readership in geography permanent, and geography is recognised as an optional subject in the B.A. degree (Appendix XXXVIII.).

Victoria University now makes geography an optional subject in its first (preliminary) examination for the B.A. and B.Sc. degrees. An outline of the requirements of candidates will be found in Appendix XXXIX.

Scotland and Ireland.—These institutions do not recognise geography as a subject of university rank, and deal with it only in their entrance examinations (and in the case of St. Andrews in the L.L.A. examinations, for which, however, study at a University is not required).

In Scotland this is due to no indifference on the part of the Scottish geographers, for the Royal Scottish Geographical Society, supported by

several professors, have made strong representations to the University Commissioners, who have recently remodelled the regulations of the Scottish universities (Appendix XLII.).

University Extension Courses.

In England and Wales the university extension lecture system has done something to help teachers of geography in various centres. In 1896–97, 4 courses of 25 lectures by London University Extension Lecturers, 5 of 12 lectures by Cambridge University Extension Lecturers, 4 of 6 lectures by Oxford University Extension Lecturers, and 1 of 12 and 1 of 10 lectures by Victoria University Extension Lecturers—in all 206 lectures.

Other Institutions.

In the London School of Economics, in the Heriot-Watt (Technical and Commercial) College, Edinburgh, there are lecturers in geography. The London Chamber of Commerce and other bodies have aided in the extension of geographical knowledge. The number of professional colleges and schools teaching applied geography is small, although the specialised branches of the subject ought to be dealt with in such institutions and not in the ordinary schools. The absence of Commercial Geography from the courses of many Higher Commercial Institutions is greatly to be deplored.

Foreign.

In the April number of 'Petermann's Mitteilungen,' there is a list of classes held and lectures being delivered at the universities and higher schools in the German Empire, and the German parts of Austria and Switzerland, on geography and allied subjects during the summer session of 1897. From this list it appears that 85 professors in the German Empire, 20 in Austria, and 9 in Switzerland are engaged in such work, and if we omit the courses in geology and meteorology, and general courses in statistics, anthropology, and ethnology, we find 51 professors in the German Empire, 11 in Austria, and 5 in Switzerland, giving courses in subjects that may be held as belonging more strictly to the domain of geography, the number of courses being 98, 17, and 16 respectively. . . . It would shed an instructive light on the difference of the estimation in which geography is held as a branch of the higher education in this country if we had for comparison a similar list for the United Kingdom, and in the absence of such a list it may be worth while to point out that in the list of the University Extension summer courses, given in the April number of the 'University Extension Journal,' there are only 5 geographical courses, and even if we double this number so as to take into account the classes held after lectures . . . we have only 10 summer courses in England (in addition to any university courses that may be going on), to compare with the 131 courses in German Europe.[1]

In the 'Geographisches Jahrbuch' for 1896, the following are the numbers of geographical chairs and lectureships in the universities and colleges of the chief countries :—France, 41 ; German Empire, 35 ; Austria, 16 ; Italy, 16 ; Russia, 15 ; Belgium, 7 ; Switzerland, 7 ; United Kingdom, 5. The lecturers in the university colleges should perhaps be added to the

[1] *Geographical Journal*, June 1897, pp. 660, 661.

number for the United Kingdom, which would then be raised. But it is better to deduct every teacher in the foreign institutions who has more than geography within his province, even though it be meteorology or ethnography, geology or history; then the figures are—for the German Empire, 31; France, 28; Austria, 16; Italy, 11; and the United Kingdom, 5. These figures do not include geographers such as Professors de Lapparent and Levasseur in France, Oberhummer in Germany, Boyd Dawkins and Lapworth in England, whose chairs combine geography with other subjects.

The position and nature of geographical work in Austrian and Belgian universities is noted in Appendices XL. and XLI.

4. *GEOGRAPHICAL SOCIETIES AND PUBLICATIONS.*

Any report on the position of geography in the educational system of the country would be incomplete if it omitted to notice the excellent work being done by the five British geographical societies. All of these, by their lectures and publications, have done much to spread an interest in, and true knowledge of, geography throughout the country.

They have supported the better teaching of geography in our schools and colleges, by giving awards, subscriptions, and other encouragement. The Royal Geographical Society has trained many explorers. The lectureships at Oxford and Cambridge are due to the initiative and hitherto largely to the financial support of the Royal Geographical Society, and the independent lectureship at the Owens College, Manchester, was maintained at the joint cost of the Royal and the Manchester Geographical Societies.

Short statements of the educational work done by British geographical societies are given in Appendix XLII.

In the last anniversary address to the Royal Geographical Society ('Geographical Journal,' June, 1897), Sir Clements Markham, the President, outlined some of the educational schemes of the society:—

(*a*) *The Training of Explorers.*—'A diploma is to be granted to those pupils of Mr. Coles who have gone through a complete course of instruction, and whose sufficiency is certified to by a committee, consisting of the instructor and two members of our Council.'

(*b*) *The Training of Teachers.*—'The Council has now resolved to give a large measure of support, out of the Society's funds, to a London School of Geography, if such an institution should be successfully established under Mr. Mackinder's auspices. Our plans have been altered, as we acquired experience, but our aim has always been the same—to train good geographical teachers, and to promote the teaching of geography on a sound basis in our secondary schools and universities.'

The number of geographical societies in the United Kingdom is small, 5, when compared with 26 in France, 21 in Germany, 10 in Russia and 5 in Switzerland. The membership in the British societies is large, but the Royal Geographical Society has more than half the total number of members of the British societies. Of the 153 geographical publications which appear regularly, 48 are in French, 42 in German, 15 in English (6 American, 5 British, and 4 Australian), 12 in Russian, &c.

In Germany, France, Switzerland, and Italy, National Geographical

Congresses are held. The Geographical Section of the British Association, perhaps, may be compared with them, and it has undoubtedly helped greatly in spreading an interest in geographical science.

5. *CONCLUSION.*

In this report the questions of methods of teaching geography, the importance of good maps and appliances, the need of open-air and museum teaching as well as of frequent excursions, are not discussed, although in the improvement of our methods lies much of the hope for the future. At present, in the minds of many people, including some of our educational authorities, there is a very vague conception of the scope of geography and its educational value. We lack geographical traditions in the British Isles, and will continue to be without them as long as our teachers of geography are mainly self-taught or trained in different foreign schools.

Elementary Education.—In all elementary schools geography should be made a compulsory subject, and the syllabuses of the different standards modified as has been suggested on page 372; while instructions to inspectors (see Appendix II.) should be improved, and embody loftier educational ideals, such as those so admirably outlined in the 'Instructions, Programmes et Règlements. Enseignement Secondaire,' issued to teachers by the French Education Department in 1890 (pp. 89 to 104).

But the position of geography in our elementary schools could be very much improved, without altering the present syllabuses, if properly trained teachers in geography and a satisfactory equipment of geographical apparatus could be found in every school.

The first requirement for the progress of geography is that the teachers themselves should be interested in the subject, and that they should be given the means of a thorough geographical education in the training colleges. Geography is, next to English, the most commonly taught subject under the present system, and therefore every elementary school teacher should have a thorough grounding in modern geographical methods and ideas. Its importance in the elementary school warrants its being a compulsory subject in every year of the training college curriculum. The spirit of the teaching, both in school and in college, should be 'education through geography,' the summary of the French work just mentioned.

Secondary Education.—The utilitarian as well as the educational value of geography should ensure its being taught in every class and form of our secondary schools, as is the case in France. Most subjects taught in school have a geographical side, and are made more intelligible by a knowledge of geography on the part of teacher and scholar; and geography should have an assured and independent place in every entrance examination to universities or professional colleges.

All secondary school teachers, however, will not need to teach geography, and so all need not be geographers. Those who have charge of the geography classes, however, should have had an adequate geographical training, preferably at one of our universities.

Higher Education.—In our universities geography should have its due place, equivalent to that of any other university subject now fully recognised. For degree examinations it should be an optional subject, both in

arts and science. It should be compulsory for some students in a minor standard, for instance, for students reading for honours in history, or anthropology and ethnology, or economics or geology. Teachers of geography in the lower classes of secondary schools should have passed in geography in this lower standard, while those responsible for the teaching of geography in the highest classes should have taken honours in geography. The universities should therefore provide the skilled teaching and efficient equipment that are necessary for a subject regarded as of first-rate importance by nearly every first-class university outside the English-speaking lands.

In all technical, commercial, and professional schools, general as well as applied geography should have a more prominent place in the curriculum than it occupies at present, both from an educational and utilitarian point of view. This is of special importance in the case of commercial colleges at a time when the competition for the markets of the world is becoming very keen, and every little advantage of superior general knowledge, such as economic geography, properly taught, can supply, counts for much.

The Chairman of the Committee was unfortunately prevented from attending the meetings of the Committee after the first one, and Mr. Sowerbutts was unfortunately too ill to be present when the final report was considered. Both members, however, have had an opportunity of revising the report. Mr. Sowerbutts wishes to lay even greater emphasis on the importance of Commercial Geography for a commercial nation.

APPENDICES.

NOTE.—In addition to the appendices given here the reader is referred to the numerous programmes, examination papers, and opinions on geography printed with Dr. J. Scott Keltie's Report on Geographical Education.

An admirable account of the position of geography in the educational system of France was given by Professor Levasseur to the Sixth International Geographical Congress in 1895. See Report of Congress, pp. 27–71.

Professor du Fief gives a similar account, applicable to Belgium, in the 'Bulletin de la Société royale belge de Géographie,' xvi.

Professor H. Wagner's papers on 'Methodik und Studium der Erdkunde' in the 'Geographisches Jahrbuch' should also be consulted.

Some recent papers on Geographical Education were reviewed, in the 'Scottish Geographical Magazine' for 1896, by Mr. A. J. Herbertson, and those containing bibliographical notes were specially mentioned.

A small volume for the use of teachers, 'Hints to Teachers and Students on the Choice of Geographical Books' (Longmans, 1897) has been compiled by Dr. H. R. Mill.

1. *ELEMENTARY EDUCATION.*

I.—The Day School Code,

—	Standard I.	Standard II.	Standard III.
Geography:	A plan of the school and playground. The four cardinal points. The meaning and use of a map.	The size and shape of the world. Geographical terms simply explained, and illustrated by reference to the map of England. Physical geography of hills and rivers.	Physical and political geography of England, with special knowledge of the district in which the school is situated.
Alternative Courses:			
Course A . .	Plan of school and playground. Meaning and use of a map. The cardinal points.	Size and shape of the world. Geographical terms simply explained. Physical geography of hills and rivers, illustrated by reference to the map of England.	Physical, political, and industrial geography of England, with special knowledge of the district in which the school is situated.
Course B . . .	Plan of school and playground. Meaning and use of a map. The cardinal points.	Home geography, *e.g.* roads, rivers, and chief buildings of the district, illustrated by a map, and by the map of England.	General geography of England and Wales, and means of communication by land and water. Chief industries and productions of the district in which the school is situated.
Course C. Geography and History combined.	Plan of school and playground. Meaning and use of a map. The cardinal points.	The size and shape of the world. Geographical terms simply explained and illustrated by reference to the map of England. Physical geography of hills and rivers.	Physical and political geography of England, with special knowledge of the district in which the school is situated.
Alternative Course in Geography for Schools which take other class subjects in the lowest three Standards.			

A. ELEMENTARY SCHOOLS.

England and Wales, 1897.

Standard IV.	Standard V.	Standard VI.	Standard VII.
Physical and political geography of the British Isles, and of British North America or Australasia, with knowledge of their productions.	Geography of Europe, physical and political. Latitude and longitude. Day and night. The seasons.	The British Colonies and dependencies. Interchange of productions. Circumstances which determine climate.	The United States, Tides and chief ocean currents.
Physical and political geography of Scotland and Ireland and of the United States of America. Day and night. The air, mists, fogs, clouds, rain, frost, wind, and the special circumstances which determine climate and rainfall in the British Islands.	Physical and political geography of Europe. Industries and productions of its several countries. Latitude and longitude. The seasons.	Physical and political geography of Australia, New Zealand, Canada, and the South African colonies, India and Ceylon. Climate as affected by latitude, altitude, rainfall, forests, nearness to the sea, ocean currents, and prevailing winds.	The general arrangement of the planetary system. The sun. The moon and its phases. The tides. Eclipses.
General geography of Scotland, Ireland, Canada, and the United States, with special reference to the interchange of productions between those countries and England. Geography of Europe generally, and of either Canada or Australia.	General geography of Europe, with special reference to the commercial relations between the countries of the Continent and Great Britain.	General geography of Australia and British India, with special reference to the industries of those countries, and to their commercial relations with Great Britain. Colonisation.	General geography of Asia and Africa, with special reference to their productions and trade. Colonisation and the conditions of successful industry in British possessions generally.
Geographical terms simply explained and illustrated by reference to the map of England, and to some of the leading countries of the world selected by the teacher.	Physical and political geography of the British Isles.	Physical and political geography of Australia, Canada, and South African colonies, India and Ceylon. Four of the chief lines of communication between Great Britain and other centres of commerce. Latitude and longitude.	The British Colonies and dependencies. The interchange of productions between Great Britain and her colonies and the United States. The seasons.

II.—Revised Instructions to H.M. Inspectors. England and Wales, 1897.

32. To obtain the mark 'good' for Geography the scholars in Standard V. and upwards, not being half-timers, should be required to have prepared three maps, one of which, selected by the Inspector, should be drawn from memory on the day of inspection. Such maps, if of any part of Great Britain and Ireland, should be accompanied by a scale of miles, and if of large and distant countries by the lines of latitude and longitude. Geographical teaching is sometimes too much restricted to the pointing out of places on a map, or to the learning by heart of definitions, statistics, or lists of proper names. Such details, if they form the staple of the instruction, are very barren and uninteresting. Geography, if taught to good purpose, includes also a description of the physical aspects of the countries, and seeks to establish some associations between the names of places and those historical, social, or industrial facts which alone make the names of places worth remembering. It is especially desirable, in your examination of the Fourth and higher Standards, that attention should be called to the English (*sic!*) Colonies and their productions, government, and resources, and to those climatic and other conditions which render our distant possessions suitable fields for emigration and for honourable enterprise. In order that the conditions laid down for the geographical teaching of the lower classes may be fulfilled, a globe and good maps, both of the county and of the parish or immediate neighbourhood in which the school is situated, should form part of the school apparatus, and the exact distances of a few near and familiar places should be known. It is useful to mark on the floor of the schoolroom the meridian line, in order that the points of the compass shall be known in relation to the school itself, as well as on a map.

III.—Code of Regulations for Day Schools in Scotland, 1897.

—	Standard I.	Standard II.	Standard III.	Standard IV.	Standard V.	Standard VI.
Geography	To explain a plan of the school and playground. The four cardinal points. The meaning and use of a map.	The size and shape of the world. Geographical terms simply explained, and illustrated by reference to the map of Scotland. Physical geography of hills and rivers.	Physical and political geography of Scotland, with special knowledge of the district in which the school is situated.	The physical and political geography of the British Isles.	The physical and political geography of Europe, with British North America and Australasia.	The geography of the world in outline, and in more detail Europe and the British Colonies. Some elements of physical geography.

IV.—Programme of Instruction and Examination for Pupils of National Schools, Ireland.

First and Second Class.—No geography.

Third Class.—6. *Geography.* To know the outlines and leading features of the Map of the World.

FOURTH CLASS.—6. *Geography.* (*a*) To know the ordinary geographical definitions of the physical divisions of land and water. (*b*) To be acquainted with the Maps of the World and Ireland.[1]

FIFTH CLASS, FIRST STAGE.—6. *Geography.* (*a*) To understand longitude, latitude, zones, &c. (*b*) To know the *Map* of Europe and *Map* of Ireland.

FIFTH CLASS, SECOND STAGE.—6. *Geography.* (*a*) To understand longitude, latitude, zones, &c. (*b*) To know the *Maps* of the Continents. (*c*) To be acquainted with the geography of Ireland.

SIXTH CLASS.—6. *Geography.* (*a*) To be acquainted with the elements of mathematical and physical Geography. (*b*) To draw *from memory* an outline map of Ireland. (*c*) To know the geography of Great Britain and Ireland, India, and the British Colonies.

Science Programmes for Pupils of Fifth Class and Higher.

Physical Geography.

FIRST EXAMINATION.—Distribution of land and water—zones—climates—temperatures. Mountains—table lands—plains—deserts.

SECOND EXAMINATION.—Rivers—lakes—tides and currents—atmosphere, its properties and uses—reflection and refraction of light by atmosphere—evaporation—clouds—rain—dew—hail—winds, three kinds of—hurricanes—cyclones—typhoons—hot winds—distribution of plants and animals—relation of horizontal and vertical distribution—different races of men and how distributed.

V.—PROGRAMMES IN AUSTRIAN ELEMENTARY SCHOOLS.

Elementary Schools with Five Classes.

Scheme: Knowledge of the child's Home Region and Native Land. General knowledge of Europe and the Earth.

III. Home lore, starting from the School. Fixing of the most important geographical principles.

IV. Lower Austria. Survey of the Austro-Hungarian Monarchy. Typical geographical character sketches.

V. The Austro-Hungarian Monarchy. The essential and most useful facts of the political divisions of Europe. The Globe and its surface. Pertinent geographical character sketches from reading-book. Map drawing.

Programme of Geography in the Austrian 'Bürgerschule' with Three Classes.

General Idea of Course.—Knowledge of the most important sections of Mathematical and Physical Geography.

A general knowledge of Europe and the other Continents.

A special knowledge of the Austro-Hungarian Monarchy, Industry, Trade, while attention must be paid to the mutual movements of the people and the characteristic products of the countries.

[1] The map of the county in which the school is situate may be substituted for the map of Ireland in the Fourth Class.

FIRST CLASS.—Elements of Mathematical Geography; horizon; directions. Form and size of the earth. The Globe (meridians and parallels, geographical longitude and latitude). Rotation of Earth. Day and Night. Revolution of Earth. The Seasons.

Elements of Physical Geography.—General sketch of the different parts of the Earth and their horizontal and vertical distribution, with especial attention to Central Europe. The Native Land. Map drawing.

SECOND CLASS.—Revision of work done in Class I. The Moon. Eclipses. General sketch of the world, its political divisions, especially of the Austro-Hungarian Monarchy. 'Culturbilder.' Map drawing.

THIRD CLASS.—Revisal of Mathematical Geography. The Solar System. Thorough study of the Austro-Hungarian Monarchy and its relationship to other lands, with special attention to industry and commerce. General comprehension of Political Geography. 'Culturbilder.' Map drawing.

VI.—OFFICIAL PROGRAMME FOR PRIMARY SCHOOLS, BELGIUM (FROM DECEMBER 28, 1884).

Elementary Course.

1. The cardinal points: method of orientation by observing the position of the sun. Exercises. The intermediate points.
2. *Plans.*—The class-room, the school, the street, the land covered with buildings, the commune: (*a*) teaching how to read the plan; (*b*) how to draw it: 1st, the chief parts of the plan; 2nd, the cardinal and then the intermediate points.
3. Conversations about the home region: geographical phenomena and terms for them, natural productions, occupations of men, industry and commerce. Walks and excursions.
4. First idea of the canton.
5. The visible horizon; the form of the earth; the earth isolated in space; first observations and simple explanations.
6. Show on the globe: (*a*) land and water; (*b*) the five divisions of the globe and the oceans.
7. Point out the position of Belgium and the surrounding countries on the globe.

Intermediate Course.

1. *Orientation.*—Revision of what was learned in the elementary course.
2. *Plans and Maps.*—(*a*) Make children draw plan of the playground, and of the street, and orient the plans.

(*b*) Lessons in reading simplified maps of the commune.
(*c*) Reading of the map of canton.
(*d*) Drawing from memory different sketches relative to communal and cantonal maps. Ideas of distance.

3. First notions of the globe.
4. General divisions of globe—the five parts of the world and the oceans.

5. Boundaries of the five parts of the globe. Some of the great world voyages (Columbus, Magellan, &c.), in order to familiarise the pupils with a knowledge of the great divisions of the globe.

Show on the globe and on maps the chief European States and their capitals.

6. *Belgium.*—(*a*) Boundaries, shape, area, population; compare with other States, people, and languages.

(*b*) Explanation of principal terms used in political geography—commune, canton, arrondissement, province, &c.

(*c*) Division of Belgium into provinces. Boundaries and chief towns of each province.

(*d*) Physical Geography. General aspect of country—plains, hills, plateaux, and valleys. Water partings and river basins. Course of the Scheldt and the Meuse and their chief tributaries.

(*e*) Detailed description of home region.

Map drawing from memory of the map of the province, and other sketches.

N.B.—If time permits the teacher may begin the more advanced study of Belgium given in the following programme:—

Advanced Course.

1. *Belgium.*—Revision of preceding course. More advanced study of its physical geography; the chief watercourses. Important productions of the three kingdoms. Agricultural regions. Great industrial centres. Commerce, transport routes by land and water, imports and exports.

Summary description of each of the nine provinces.

Sketches and maps drawn from memory.

Exercises in the use of Belgian railway time-tables.

2. *Europe.*—Summary description of coasts, seas, gulfs, straits, large islands, and peninsulas.

Chief countries in Europe: boundaries, government, chief towns, natural wealth, industry, most important commercial relations with Belgium.

3. General ideas, very succinct, of Asia, Africa, America, and Oceania.

Accounts of some great explorations, the route being traced in chalk on the black globe.

Optional.

4. *Maps.*—Reading a graduated series of maps of the commune, and making sketches.

5. *Cosmography.*—Orientation by the compass, by pole star.

Latitude, longitude. Determination of a point on the surface of the sphere.

Distances on a sphere. Dimensions of the earth.

Rotation and revolution of the earth.

The phases of the moon, eclipses and comets.

VII.—Official Programme for Primary Schools, France (from January 18, 1887).

Infants (5–7 years).

Familiar talks and simple preparatory exercises, designed above all to stimulate the habit of observation among children by making them look

carefully at the most common phenomena and the chief features of the land's surface.

Elementary Course (7–9 years).

Continuation and development of the exercises of the previous stage. The points of the compass, not learned by heart, but discovered in the field, in the playground, during walks, and according to the position of the sun.

Exercises in observation : the seasons, the chief atmospheric phenomena, the horizon, the nature of the land's surface, &c.

Explanation of geographical terms (mountains, rivers, seas, gulfs, isthmuses, straits, &c.), always beginning from objects seen by the pupil and proceeding by analogy.

Preparatory study of geography by intuitive and descriptive methods:

1st. Local geography (house, street, village, commune, canton, &c.).

2nd. General geography (the earth, its form and dimensions, its great divisions and their subdivisions).

The notion of cartographic representation : the elements of plan and map reading.

The terrestrial globe, continents and oceans.

Conversations about the home region.

Intermediate Course (9–11 years).

Geography of France and its colonies.

Physical geography.

Political geography, with more detailed study of the home canton the département, and the region.

Exercises in map drawing on the blackboard, and on note books, without tracing.

Advanced Course (11–13 years).

Revision and development of the geography of France.

Physical and political geography of Europe.

More summary treatment of the geography of the other continents.

French colonies.

Map drawing from memory.

VIII.—Code of Regulations and Reports on Evening Continuation Schools, England and Wales and Scotland, (1897).

Geography.

General geography of the British Isles, their chief industries and means of communication by land and water.

General geography of Canada and the United States, or of Europe or Australasia or British India, with special reference in each case to their industries and to their commercial relations with Great Britain.

Colonisation and the conditions of successful industry in the British possessions generally.

B. TRAINING OF ELEMENTARY SCHOOL TEACHERS.

IX.—Code for Pupil Teachers before and during Engagement. England and Wales, 1897.

Geography.

In Welsh districts, in the 2nd Division, one question will be set on the physical and political geography of Wales at the present time, and in the 3rd Division one question on the commercial geography of Wales at the present time.

1st Division: Physical, political, and commercial geography of the British Islands, British North America, and Australia.
Maps of British Isles.

2nd Division: Europe and Asia (with special reference to British India).
Maps of France, Italy, and British India.

3rd Division: Africa, America, Australasia, and Polynesia.
Maps of Australia, North America.

X.—Regulations relating to the Examination of Candidates for Admission into Training Colleges and for the Office of Assistant Teacher, called the Queen's Scholarship Examination. England and Wales, 1895 and 1896.

Geography. [70] in 1895, [100] in 1896.

1. Physical, political, and commercial geography of the British Empire.
2. Map drawing. The map set will be some part of the British Islands, France, or Italy (1895). British Islands or Hindustan (1896).

In Welsh districts some of the questions set will relate to Welsh geography and Welsh industries.

XI.—Training Colleges, England and Wales. Examination for Teachers' Certificates, 1895–97.

First and Second Years. Male and Female Candidates.

Geography and History.—A candidate who has, at the Queen's Scholarship Examination in one of the two preceding years, passed with exceptional credit in geography or history, is released from the obligation to take up the subject again at the first year's examination, and may substitute for each subject in which he has so passed a language or a science.

Geography.—[75.] 1. Elementary knowledge of physical geography, with special reference to—

(*a*) Shape, size, and motions of the earth.
(*b*) The atmosphere, rain, clouds, and vapour.
(*c*) Winds, currents, and tides.
(*d*) Causes which affect climate.

2. General geography of Europe, with maps of *any part of England.*

In 1895–6. (*e*) *Effect of climate on industry, productions, and national*

character; (f) Distribution of plants and animals will be added to Section 1, and 'the British Empire, with maps of Australia, Hindostan, and New Zealand,' will be substituted for 'Europe, with maps of any part of England,' in Section 2.

In 1897, general geography of Africa, with maps of British South Africa and Egypt.

(Section 1 omitted from syllabus printed in Annual Report, 1895–96.)

XII.—Code of Pupil Teachers before and during Engagement. Scotland, 1897.

Geography.

First Year.—The British Isles, Australia, and British North America. Elements of physical geography. (Maps to be drawn in this and the following years.)

Second Year.—Europe and British India. Latitude and longitude. Climate and productions of the British possessions.

Third Year.—Geography of the world generally, with special reference to British Isles and British possessions. More advanced physical geography.

XIII.—Regulations relating to the Queen's Scholarship Examination. Scotland, 1896.

Geography. [50.]

Physical, political, and commercial geography of the world, with special reference to the British Isles and British possessions.

Answers may be required to be illustrated by sketch maps.

Candidates who pass with credit in this subject at the Queen's Scholarship and Studentship Examination may, in the *next two* examinations for certificates open to them, omit the paper in Geography, and take an extra Language or Science instead. Candidates who fail to pass in this subject will be marked 'G' in this class list.

Note.—*With a view of encouraging the study of this subject, the Council of the Royal Geographical Society offer three prizes of 2l. each with certificates to male, and three to female candidates, and five certificates without money prizes to male, and five to female candidates who obtain the highest marks in Geography at the Queen's Scholarship and Studentship Examination.*

XIV.—Training Colleges, Scotland. Examination for Teacher's Certificate, 1895, 1896. First and Second Years. Male and Female Certificates.

Geography and Physiography. [100] in 1895, [75] in 1896.

1. An elementary knowledge of physical geography, comprehending the composition and phenomena of the earth's crust; the motions of the earth; the seasons.
2. The *general* geography of *Europe* in connexion with commercial and industrial geography.

Candidates may be asked to illustrate their answers by sketch maps.

1. *In* 1896 *the Tides, Winds, and Ocean Currents will be added to Section* 1.

2. *In* 1896 *the Physical Geography of Asia and the British Islands in connexion with Commercial and Industrial Geography, will replace Section* 2.

NOTES (1896.)—(*a*) *Candidates who passed with credit in this subject at the Queen's Scholarship Examination in July or December* 1894 *may omit it at this Examination, and will be credited with the marks gained.*

(*b*) *Candidates who now—July* 1896—*pass with credit in this subject may omit it at the Certificate Examination of* 1897 *or* 1898, *and may then take an extra Language or Science instead.*

(*c*) *Candidates who now—July* 1896—*fail to pass with credit in this subject will be marked 'G' in the Class List, and will be required to take it again at any subsequent Examination for Certificates.*

(*d*) *Marks for success in this subject at this Examination will not be carried forward to any future Examination for Certificates.*

XV.—PROGRAMME FOR MONITORS, IRELAND, 1897.

Extra geography is prescribed from Sullivan's 'Generalised Geography,' in addition to that for the class in which monitor is enrolled.

XVI.—REVISED PROGRAMME OF EXAMINATION FOR ADMISSION TO TRAINING COLLEGES, AND FOR THE CLASSIFICATION AND PROMOTION OF TEACHERS AND QUEEN'S SCHOLARS, IRELAND, 1897.

Subject	Marks	Entrance	Marks	First Year	Marks	Second Year
GEOGRAPHY	70	Elementary general geography (political and descriptive) Mathematical geography. Form, size, and motions of the earth To draw an outline map of Ireland showing the principal mountains and rivers	70	(*a*) The British Empire (political and descriptive), with special reference to its commercial aspect (*b*) Physical geography. Mountains, plains, rivers, deserts, winds, climates, tides, and currents (*c*) To draw an outline map of Great Britain or a certain portion of it, showing principal mountains and rivers	70	Same course (optional for those who have passed in Col. 2 with not less than 60 per cent. of marks)

N.B.—An old programme may be chosen as an alternative in 1897 and 1898.

XVII.—PROGRAMME OF EXAMINATION OF CANDIDATES FOR ADMISSION TO THE OFFICE OF INSPECTOR OF NATIONAL SCHOOLS, 1890.

Obligatory Subjects.

Geography.—Sullivan's 'Geography Generalised,' 500 marks.

XVIII.—PROGRAMME OF EXAMINATION FOR INSPECTORS' ASSISTANTS.

Geography.—Sullivan's 'Geography Generalised,' including chapters on history, 400 marks.

XIX.—Programme of Course in Geography in the Austrian Training Colleges.

Elementary Teachers, 'Volkschule.'

Understanding of maps and globes. Knowledge of the earth's surface, physical and political, especially Europe, and more particulary Central Europe. Map drawing, and geographical representation of the chief elements of physical geography.

Teachers, 'Bürgerschule.'

Mathematical, physical, and political geography of the world, of Europe, and especially of Central Europe, and a thorough knowledge of geography of native land.

Knowledge of the Constitution and Organisation of the Austro-Hungarian monarchy in general.

General knowledge of commercial geography.

Accuracy in dealing with comparative geography.

Skill in map-drawing, and in the graphic representation of physical geography.

XX.—Programme of Course in Geography in the Training Colleges of the Grand Duchy of Baden.

First Course.—General geography. More detailed knowledge of Germany.

Second Course.—The five continents, with more detailed treatment of Europe.

Third Course.—Mathematical and physical geography. Knowledge of the solar system.

In teaching geography emphasis is to be laid upon the intelligent understanding of a map, and upon graphic descriptions of interesting geographical incidents.

To this end globes and maps—without the political divisions—showing the oro- and hydrographical relations, also the distribution of temperature and of cultivated plants, should be selected for the earlier lessons. Political geography comes later.

Whilst in the preparatory school attention is more directed to topographical relations, in the training colleges it is more important to keep in view the nature of the countries, their climatic conditions, their characteristic animal and plant forms, and the life and occupations of the people who inhabit them and are dependent on the soil for their livelihood.

The various countries will be treated with more or less detail according to their importance.

Map-drawing is to be diligently practised. In map-drawing the pupils are to be so far advanced that they can draw a map of the school district on an enlarged scale, showing all the geographical features.

In the methodical introduction to geographical teaching liberal use is to be made of atlases, wall maps, globes, telluria, and other apparatus in illustration.

XXI.—Ordinance of the Grand Ducal Ministry of Justice, Culture, and Education, Baden, December 19, 1884, respecting the Examination for Women Teachers.

Acquaintance with the most important points in physical and mathematical geography; general knowledge of the five continents, and special knowledge of the native land in its physical and political aspects; facility in reading maps and in the use of globes and telluria.

2. *SECONDARY EDUCATION.*

A. SECONDARY SCHOOLS.

XXII.—Public Examinations in Geography and the Secondary Schools.

A Report on the Answers received to a Circular sent out in 1894–5 *by the Committee of the Geographical Association.*

In considering the best means of improving the teaching of geography in Secondary Schools, the Committee was soon driven to the conclusion that one of its earliest tasks must be to approach the various Boards of Public Examiners.

For the schools are necessarily compelled to adapt their teaching to the requirements of the examinations for which they prepare their pupils. And it is felt by the Committee that geography can never take its proper place among subjects that train and educate the mind, so long as the teaching of geographical principles is neglected, and the subject treated as a mass of isolated facts, to be acquired by unintelligent cramming.

They therefore addressed themselves in the first instance to the Educational Committees of the Royal Geographical Society and the Royal Colonial Institute; and having received an assurance of their sympathy and approval, they drew up four suggestions which they sent out in the form of questions to about 300 Secondary Schools. To these questions 92 answers have been received, including expressions of opinions from nearly all the great Public Schools—a result that the Committee regard as satisfactory, considering the apathy that prevails on the subject of geography in so many of our Secondary Schools.

The following are the suggestions, together with a summary of the opinions elicited in reply:—

(i.) *That papers in Geography should be set and looked over by Geographical experts.*

This meets with general approval, provided always that the examiner has had experience in teaching and examining boys.

(ii.) *That the principles of Physical Geography should form part of every examination* [in Geography].

This is almost universally accepted, but a general wish is expressed that the term Physical Geography should be limited and defined.

(iii.) *That the subject 'Geography' as set, especially in the Army Examinations, is too wide and too vague, and that a subdivision of it would be a great advantage, so as to include, besides the principles of Physical*

Geography, the Physical, Political, Historical, and Commercial Geography of some Continent.

All are agreed that the subject is at present too wide and vague, and many express the wish that a syllabus or text-book should be issued by authority for the guidance of teachers and examiners alike.

The suggestion that the Geography of some particular Continent should be set for each examination finds many supporters, but the weight of opinion is in favour of requiring a general knowledge of the Geography of the earth, as well as a special study of some selected area, such as a Continent, India, or the British Colonies, the subject to vary from time to time.

It is also suggested that a larger choice of questions should be given, of which the candidate should be allowed to attempt only a certain number.

(iv.) *That in Competitive Examinations Geography ought either to be compulsory or to receive a sufficient number of marks to make it 'pay.'*

As regards the Army Examinations, it is generally felt that Geography ought to be a compulsory subject, and many think that the marks at present assigned to it are insufficient. Some regret the abolition of the Army Preliminary Examination ; but a few declare themselves to be well satisfied with the present arrangement.

As to other Examinations, opinion is divided ; and while many would be glad to see more weight given to Geography, they point out that this could only be done by sacrificing some other subject, and they deprecate any action that would tend to increase the existing strain and pressure.

XXIIA.—Memorandum of Reforms in Examinations in Geography Advocated by the Committee of the Geographical Association.

1. That the main principles of Physical Geography should form the basis of Geographical teaching at all stages, and should be fully recognised in all Examinations in Geography.

2. That a general knowledge of Geography, based on Physical Principles, should be required, together with a special study of some selected region, *e.g.* India, a group of British Colonies, South America, Central Europe.

3. That it is desirable that all Public Examining Bodies, such as the Civil Service Commissioners, the Universities (in their Local and Certificate Examinations, and London Matriculation), and the College of Preceptors, should recommend a course of instruction in accordance with the ideas suggested above. This would stimulate Geographical teaching in Schools, ensure that Geography should be systematically taught throughout the School, and do away with the need for separate classes to prepare candidates specially for the various Public Examinations in Geography.

4. That in the Examinations above referred to, Geography and History should be dealt with in separate papers, and that the maximum of marks should be approximately the same for each.

XXIII.—Geography in the Entrance or Matriculation Examinations of English Universities or University Examination Boards.

Cambridge.

No examination.

Durham.

No geography

London.

No geography.

'English History and the Geography relating thereto' is one subject, and in January 1897 'A map of England at the close of the reign of Alfred' was one of the questions that might be chosen.

Oxford.

No examination.

Victoria.

'English Language and Composition, English History with Geography' is a subject; the fifth section of the syllabus reads 'Elements of Political Geography, especially of Great Britain and Ireland.'

XXIV.—Oxford and Cambridge Schools Examination Board Regulations.

Higher Certificates.

Candidates who offer Physical Geography and Elementary Geology shall be examined in—

(*a*) The outlines of Physical Geography: viz. the form of the earth and variations in the earth's surface; the force of gravity; the seasons; the atmosphere and climate, winds, clouds, rain and dew, the ocean, tides, seas, lakes and rivers, glaciers and icebergs, volcanoes and earthquakes.

(*b*) The outlines of Geology: viz. the principal igneous, aqueous, and metamorphic rocks, including recognition of specimens; denudation; deposition of stratified rocks, dip, strike, joints, cleavage, faults, dykes; unconformable stratification; the principles on which the relative ages of rocks are determined; the outlines of stratigraphical geology; the recognition of the fossil genera found in the principal formations.

Examination for Lower Certificates.

[N.B.—This Examination is adapted for Candidates of sixteen years of age.]

In Geography, questions shall be set on General Geography, and on the Geography of the British Isles and of some other country to be selected.

For the examination in 1898 the selected country shall be the German Empire.

The questions shall be set on the assumption that the main principles of Physical Geography form the basis of geographical teaching.

XXV.—Geography in the Examinations of the College of Preceptors, 1897.

A. School Inspections.

A. ON SUBJECTS TAUGHT IN THE SCHOOL.

B. ON SYLLABUSES OF COLLEGE OF PRECEPTORS—ARRANGED FOR FOUR GRADES.

No geography in Grades I. or II.

III. 7. *Geography.*—(i.) A map—what is it? Divisions of the land, divisions of the water; (ii.) general description of England; (iii.) Europe, chief countries, chief cities, &c.

IV. 7. *Geography.*—1. The British Isles: (i.) England and Wales; (ii.) Scotland; (iii.) Ireland. 2. Europe. 3. The names, positions, chief towns, &c., of the British possessions.

EXTRA SUBJECTS.

6. *Geography* of (i.) Asia and Australasia, or (ii.) America and Africa.

7. *Physical Geography.*—(i.) Definitions; (ii.) Form of the Earth; (iii.) Distribution of Sea and Land; (iv.) Form of Continents; (v.) Mountain Systems; (vi.) Divisions of the Ocean; (vii.) Currents; (viii.) the Atmosphere and Climate; (ix.) Distribution of Plants; (x.) Distribution of Animals; (xi.) Distribution of Man. [No. 7 may be divided into two sections, A and B; Section A to include (i.)-(v.); Section B, (vi.)-(xi.)]

B. Regulations respecting the Examination of Pupils in Junior Forms.

Geography is one of the optional subjects, and consists of the geography of the British Isles, with very elementary physical geography, and the meaning of simple geographical terms.

C. Certificate Examinations and Professional Preliminary Examinations.

First Class.—One of three English subjects (English, History, Geography) forms a compulsory part of seven subjects necessary, but all three may be taken.

The syllabus reads: *Geography*, including physical and mathematical.

Second Class.—History *or* Geography is one of six subjects which must be passed, but both may be chosen.

Geography.—Candidates are required to show a general knowledge of the chief mountain ranges, rivers, outlines and boundaries of continents; names and general position of countries and their capitals, with the meaning and use of ordinary geographical terms; and a more detailed knowledge of *one* of the following, at the option of the candidate:—

1894. (*a*) Asia; (*b*) Europe, including British Isles.
1897. (*a*) Africa; (*b*) North America and the West Indian Islands.

Third Class.—History *or* Geography is one of four subjects which must be passed, but both may be chosen.

Geography.—Europe, especially the British Isles, and the meaning and use of simple geographical terms.

D. Commercial Certificate.

Holders of first or second class certificates may receive the Commercial Certificate on passing additional subjects of which Commercial Geography is *not* one.

XXVI.—Syllabus of Preliminary Examination issued by the Scottish Universities' Joint Board.

Geography forms part of the Examination in English. The Higher Grade Leaving Certificate of the Scottish Education Department is accepted as equivalent.

Arts and Science.

1. English will include Grammar, Composition, Literature, History, and Geography.

d. Geography will include a general knowledge of the geography of the world, and a special knowledge of the geography of the British Empire.

N.B.—One paper of two hours to first two. One paper of two hours for last three, half of which is literature. (Two questions in Geography are to be answered.)

Medicine.

A single paper of three hours shall be set, containing an essay, a paraphrase, two questions on history, two on geography, four on grammar (. . . .), two of a literary and general kind. Eight answers shall be required. The essay, the paraphrase, one answer on history, and one on geography shall be compulsory.

XXVII.—Leaving Certificate of Scottish Education Department. Questions in Geography, 1895.

English.

LOWER GRADE.

Tuesday, June 18, 10 A.M. *to* 12.30 P.M.

Nine *questions should be answered, and no more.* Five *of these must be in Section* I., two *in Section* II., one *in Section* III. *The remaining question may be taken from any Section. Questions* 1 *and* 2 *must be attempted.*

Section III.

14. What are the chief mountain systems of Great Britain? Where are the chief plains? Give the names of the rivers that drain them.
15. Contrast the east and the west coasts of Scotland.
16. Describe the course of the Rhine (*or* of the Danube); mention the *six* largest towns on its banks; and state in what the industry of each consists.
17. What are the chief cities on the Mediterranean? State what you know about *five* of them.
18. Write a brief account of the commerce of Cape Colony.

English.

HIGHER GRADE AND FIRST PAPER FOR HONOURS GRADE.

Tuesday, June 18, 10 A.M. *to* 1 P.M.

Every Candidate should answer TEN *questions, and no more; and every Candidate must take Questions* 1 *and* 2, *and, in addition,* THREE *other questions in Section* I.

Higher Grade Candidates must take, also, TWO *questions in Section* II., *and* TWO *in Section* III. *The remaining question may be taken from any Section.*

Honours Grade Candidates are not required to answer questions from Sections II. *and* III., *but may do so. The full number of marks can be obtained in Section* I.

SECTION III.

16. Explain, fully, the lines usually found on globes.

17. What countries border on the Baltic? What are the chief Baltic ports, and in what does their trade consist?

18. What countries in Europe are (*a*) best supplied with railways and telegraphs, and (*b*) what are most poorly supplied? Give the reasons in each case.

19. Write a short account of the build of South America, under the heads of (*a*) plateaux, (*b*) mountain ranges, (*c*) plains. State what you know about the Amazon and the Cassiquiare.

20. Write a short account of the geography of India; and give the names of the chief peoples, languages, and religions.

21. State what you know about the six chief trading cities of China.

N.B.—See Sir Henry Craik's report on geography papers in this examination.

XXVIII.—INTERMEDIATE EDUCATION BOARD FOR IRELAND. PROGRAMME.

Preparatory Grade.

Geography: The meaning and use of Maps; size and shape of the Earth; Geographical terms simply explained and illustrated by special reference to the Map of Ireland; general outlines of the great divisions of the Globe; outlines of the Physical and Political Geography of Ireland. 200 marks (Greek and Latin 1200 each).

Junior Grade.

Geography: Outlines of the Geography of the World, including Distribution of Land and Water, and their relative position and areas; Mountain Chains and Systems; Seas and Oceans; Rivers and Lakes.

Physical and Political Geography of Great Britain and Ireland, and the Outlines of our Colonial Empire. 200 marks.

Middle Grade.

Geography: Ocean Currents, their origin and influence; Tides, their origin and influence; the Atmosphere, its constitution; Winds;

Rain; Hail; Snow; the causes affecting Climate; Day and Night; the Seasons.

Physical and Political Geography of Europe, and outlines of the remainder of the Eastern Hemisphere. An outline map of one of the countries of Europe will be given to be filled up by inserting the chief ranges of mountains, the chief towns, and the chief rivers. 150 marks.

Senior Grade.

Geography: Distribution of plants and animals; Man, as affected by conditions of external nature; distribution of races; latitude, longitude; time, how measured; the Earth's position as a planet.

Physical and Political Geography of Canada and the United States; outlines of the remainder of the Western Hemisphere. 100 marks.

COMMERCIAL ENGLISH.—*Maximum of marks*, 400.

1. Commercial Geography, comprising (*a*) its general principles; (*b*) the chief products; and (*c*) the commercial geography of the various countries. (Mill, 'Elementary Commercial Geography'; or Chisholm, 'Smaller Commercial Geography.') 150 marks.

XXIX.—GEOGRAPHY IN THE ENTRANCE EXAMINATION, TRINITY COLLEGE, DUBLIN, MICHAELMAS 1896.

History and Geography. (10 questions.)

1–5. Historical.

6. If you construct a triangle having its angles at Dublin, Londonderry, and Cork, through what counties (in order) will the sides pass?

7. In what counties are Glastonbury, Cromer, Spurn Head, St. David's Head, Coventry, Lichfield, Snowdon, Kirkwall, Paisley, Ben Nevis?

8. Name, in order of size, the five largest islands in the Mediterranean Sea. Give one town in each.

9. In which of the United States is the following: Yellowstone Park, Boston, Denver, Philadelphia, Buffalo, Sacramento, Richmond, Salt Lake City, Baltimore, Austin?

10. Where are the Falkland Islands, Mount Cook, Batavia, Bloemfontein, Poona, Aleppo, Pondicherry, Caracas, Ispahan, Monte Video?

XXX.—GEOGRAPHY IN THE ENTRANCE EXAMINATION OF THE ROYAL UNIVERSITY OF IRELAND.

English, including Outlines of Modern Geography.

Summer, 1896.—One question in Geography.

Name the principal islands in the Indian Ocean, and also the European nations within whose spheres of influence they are respectively situated.

Autumn, 1896.—One question in Geography.

6. (*a*) What lands and seas lie, westwards, between Cadiz and Cape Gracias a Dios?

(*b*) Describe the shortest course by which a ship could sail from the Thames to Yeniseisk.

XXXI.—Official Programme for Intermediate Schools, Belgium, from 1888.

A. Intermediate Schools. (Three Years' Course.)

I. General description of the Earth and its divisions. Elementary Geography of Belgium.

II. Revision of Course I. More advanced Geography of Belgium. General Geography of Europe.

III. Detailed Geography of Europe. General Geography of other parts of the World.

B. Athénées Royaux. (Seven Years' Course.)

(See Dr. Scott Keltie's Report, pp. 150, 151.)

XXXII.—Programmes in French Lycées.

Classical Side. 1½ hour per week in lower forms, 1 hour in higher forms.

Preparatory Class.

VIII. Elementary Geography of the five parts of the World.

VII. Elementary Geography of France.

VI. General Geography of the World. Geography of the Mediterranean Basin.

V. Geography of France.

IV. General Geography. Study of the American Continent.

III. Africa, Asia, and Oceania.

II. Europe.

I. France.

Modern Side. 1½ hour per week in lowest and highest forms, but only 1 hour in 4, 3, and 2.

VI. Elementary Geography of France.

V. General Geography. Europe, America.

IV. Africa, Asia, Oceania.

III. Europe.—i. General Geography of the Continent; ii. Description of the States; iii. Summary.

II. Geography of France.

I. General Geography.—i. Europe, the Six Great Powers; ii. The New World; iii. Asia, Oceania and Africa.[1]

[1] 'The headings of the syllabus for the first class,' says the official programme, 'have appeared already in those of the preceding classes. The interest of this course rests entirely in the questions the professor chooses to discuss, and the way he puts the most important. They are of every variety. It is not enough to teach the pupils, who are about to become men, what are the leading powers of the present day by their agricultural and industrial products and their commercial activity. No doubt these are important points; but these are not the only ones that should be compared. An attempt should be made to distinguish the characteristic traits of each of the States with which we have dealings, to determine in what measure the land and the people and their racial characteristics have contributed to the prosperity and power of a nation, to compare the part played in history by a people with its present condition, to realise what is the *actuality* on which we should fix our attention in each different part of the world: such are the aims of this course. It should be looked upon as the last chapter in the history of civilisation.'

B. TRAINING OF SECONDARY SCHOOL TEACHERS.

XXXIII.—EXCERPTS FROM THE REGULATIONS FOR THE EXAMINATION OF TEACHERS IN GYMNASIA AND REALSCHULEN IN AUSTRIA.

For gymnasia a teacher may choose geography and history as a chief subject, for Realschulen geography as minor subject.

The programme in geography is—

A thorough knowledge of the earth in mathematical, topographical, physical, and political aspects; a satisfactory acquaintance with European countries, together with the geography of Central Europe, especially that of the Austro-Hungarian monarchy.

The examinee must have made himself acquainted with the statistics of the Austro-Hungarian monarchy in relationship to other lands.

The present positions, conditions, and routes of international commerce must be thoroughly known.

The examinee must show readiness and certainty in every sort of graphic representation used in instruction.

XXXIV.—EXCERPTS FROM THE REGULATIONS FOR THE EXAMINATION OF TEACHERS IN MIDDLE SCHOOLS IN THE GRAND DUCHY OF BADEN.

Candidates must have been at a German gymnasium or Realgymnasium (for certain candidates), and three years at a German University.

There are three grades of examination, 3, 2, and 1. Those passing in the third grade can teach in the Sixth, Fifth, and Fourth Forms of gymnasia and modern schools (Realanstalten) with a nine years' course; those passing in the second grade, in the Lower and Upper Third and Lower Second Forms; and those passing in the first-grade, in the Upper Second and the Lower and Upper First Forms.

Only those who receive a first-class certificate in the first grade can teach in all classes.

Two major and two minor subjects must be chosen, and two major and one minor subject must belong to the group of Languages and History, or else to the group of Mathematics and Science. Geography is an exception, and may be reckoned as a major subject in *either* group. Geography must be a minor subject if history is a major subject.

The programmes in Geography are as follows:—

1. For the certificate in Geography for the *lower classes* (third grade) the candidate must show evidence of an elementary but sound knowledge of mathematical, physical, and more particularly of topographical and political geography; he must also be able to illustrate the most important facts of mathematical geography with simple apparatus.

2. To obtain the certificate for the *middle classes* (*second grade*) the candidate must possess a more thorough knowledge of the above-mentioned branches of geography, also an acquaintance with the history of discovery, and with the historically most important highways of the world's commerce.

3. The candidate for a certificate to teach in the *highest classes* (*first grade*) must be thoroughly familiar with the principles of mathematical geography, so far as these are founded on elementary mathematics, and

with the proofs of the same, and be able to give an account of the physical and most important geological conditions of the earth's surface. In addition he must have a comprehensive knowledge of the political geography of the present day, and a wide view of the historical political geography of the chief civilised peoples, together with the main facts of ethnography.

4. A readiness in map drawing is demanded from candidates in all grades.

XXXV.—Requirements of a Teacher of Geography in a Belgian Athénée Royal.

One professor teaches both history and geography. This professor, except by personal dispensation, must have either the old diploma of *Professeur agrégé de l'Enseignement Moyen pour les Humanités* or the diploma of *Docteur en Philosophie et Lettres*, the only one now given.

For the degree of *Candidat en Philosophie et Lettres* he must study geography, and, for the doctorate, geography and the history of geography.

See 'L'Enseignement Supérieur de la Géographie en Belgique,' by J. du Fief ('Bulletin de la Société Royale Belge de Géographie,' xvi. No. 3).

XXXVI.—Programme for Professors of Geography in French Lycées, 1896.

In the secondary schools of France geography is taught by a professor of history and geography . . . who must be an *agrégé.* The examination consists of (*a*) a thesis, (*b*) explanation of a passage, (*c*) giving a lesson, all of which are judged by the professors under whom the candidate has studied. The second part of the examination takes place before special examiners. The subjects for 1896 were :—

(I History.) II. Geography.

Form and divisions of globe.
Distribution of land and water.
Oceans and seas and marine currents.
Forms of terrestrial relief and the different types of mountains.
Influence of glaciers in the past on the present relief of the land.
Climates.
Vegetation zones.
Distribution of mankind.
Distribution of food products.
Configuration of Asia.
Vegetation zones of South America.
Hydrography of North America.
Ethnography of Eastern Europe.
Countries bordering the Mediterranean.
Physical geography of France.
Development of Russian colonisation in Asia.
African exploration from 1870, including Madagascar.
India. Indo-China and the Malay Peninsula.

3. *UNIVERSITY EDUCATION.*

XXXVII.—EXCERPT FROM REPORT BY MR. YULE OLDHAM, M.A., LECTURER IN GEOGRAPHY IN THE UNIVERSITY OF CAMBRIDGE, TO THE ROYAL GEOGRAPHICAL SOCIETY, MAY 1897.

'Geography has received the practical recognition of being introduced as an essential part of the new revised Historical Tripos.'

XXXVIII.—EXCERPT FROM COMMUNICATION BY MR. H. J. MACKINDER, M.A., READER IN GEOGRAPHY, UNIVERSITY OF OXFORD, ON THE POSITION OF GEOGRAPHY IN THAT UNIVERSITY.

'In almost all the papers set in the Honour School of Modern History at Oxford there are two questions on Geography, which, if well done, count considerably. As a result, the greater number of the candidates find it worth their while to attend the lectures of the Reader in Geography.

'Geography counts as an optional subject for a Pass degree, and is taken by a few candidates.'

XXXIX.—EXCERPT FROM COMMUNICATION BY PROFESSOR A. W. WARD, LL.D., D.C.L., PRINCIPAL OF THE OWENS COLLEGE, MANCHESTER, ON THE POSITION OF GEOGRAPHY IN THAT COLLEGE AND IN THE VICTORIA UNIVERSITY.

'The new Regulations (Victoria University) substitute, for the old optional Preliminary subject of Physiography, the following :—

'GEOGRAPHY.

'(*a*) *Physical Geography.*—The agents at work on and beneath the surface of the earth.

'Phenomena resulting from earth heat.

'Distribution of land and water.

'(*b*) *Political and Commercial Geography.*—Political and economic effects of Natural Features and conditions.

'Outlines of Geography of the British Empire (including Historical Geography), Political and Commercial Geography of the United Kingdom.

'You will perceive that this amounts to the inclusion of geography only in the first year's course ; but apart from the fact that it has been thought wiser, in dealing with this subject, to begin with the foundations, we were specially anxious to recognise it in the first instance as a university subject at the stage where school and university training came into contact.

'The College remains without any endowment for the teaching of geography, since both the Royal and the Manchester Geographical Societies have discontinued the grants (of 50*l.* each) made by them during periods of five and four years respectively.

'The teaching of the subject will accordingly, in this College, be for the present divided between Mr. Flux (Lecturer in Political Economy), who has been appointed Lecturer in Political and Commercial Geography, and Professor Boyd Dawkins, Professor of Geology'

SYLLABUS IN PHYSICAL GEOGRAPHY.

1. The agents at work on and beneath the Surface of the Earth—Water—Frost—Snow—Ice—The Atmosphere—Chemical Action in build-

ing up and destroying—Organic Action—The Phenomena resulting from Earth-heat—Volcanoes—Earthquakes—Elevation and Depression of Land—Mountain-making and Valley-carving—Hot Springs.

2. The Distribution of Land and Water.
3. The Distribution of the Mammalia and their evidence as to geographical changes.
4. The Distribution of Man and his Advance in Culture.
5. The Earth in relation to the Heavenly Bodies.
6. The Physical History of Britain.

SYLLABUS IN POLITICAL AND COMMERCIAL GEOGRAPHY.

The construction of Maps.

The influence of natural conditions on industry and commerce.

The Commercial Highways of the World.

The growth of the British Empire. Various forms of Government within the Empire: the chief commercial centres and principal products: the trade of the Empire.

The United Kingdom: its population, Government, industries, commerce, &c.

XL.—EXCERPTS FROM COMMUNICATIONS RECEIVED FROM PROFESSOR PENCK, OF VIENNA, ON THE POSITION OF GEOGRAPHY IN AUSTRIAN UNIVERSITIES.

'In the regulations for University examinations the word geography is scarcely mentioned, and the syllabus in it is of the most general description. That, however, lies in the nature of German University organisation. The examiner has the right to specify the range of subject in which he will examine, and thus he promotes individualisation. He can ask more from the more talented and less from the less brilliant students; can go into details in the case of specialists, &c. The University examinations are not meant to test the whole extent of the candidate's knowledge, but to prove its depth and thoroughness. . . .

'The candidate for a degree in an Austrian University has two examinations to pass, the minor one in Philosophy, the major one in two subjects in one of which he must submit a thesis. If the subject of his thesis be geographical, then he is examined in Geography, and another science, such as Geology, Meteorology, Physics, Chemistry, or History. The choice is great.'

XLI.—THE POSITION OF GEOGRAPHY IN BELGIAN UNIVERSITIES.

The entrance certificate involves having studied geography thoroughly at school for six years.

Thereafter it enters into the work of candidates for the following degrees:—

1. *Candidat en Philosophie et Lettres.* Preliminary to doctorate in these subjects. Exercises in History and Geography.
2. *Docteur en Philosophie et Lettres.* Geography and History of Geography.
3. *Candidat en Sciences Naturelles.* Elementary notions of Physical Geography.
4. *Docteur en Sciences Naturelles.* For group Sciences Minérales. Physical Geography.

5. *Ingénieur Civil des Mines.* Industrial and Commercial Geography.
6. *Candidat en Sciences Physiques et Mathématiques.* Physical Astronomy.

See L'Enseignement Supérieur de la Géographie en Belgique, by J. du Fief (Bulletin de la Société Royale Belge de Géographie, xvi. No. 3).

4. *EDUCATIONAL WORK OF GEOGRAPHICAL SOCIETIES.*

XLII.—Reports on the Educational Work of the British Geographical Societies.

Royal Geographical Society.

'The Royal Geographical Society, in addition to providing systematic training for intending explorers, has taken a leading part in improving ordinary geographical education.

'So far as can be traced, the first instance of encouragement given to general geographical instruction was through the Society of Arts. In 1866 it was resolved that a prize of 5*l.* be granted to candidates at the Society of Arts Examination for Geography. This grant continued to be made till 1873, when the Society of Arts intimated that they had discontinued the award of a prize for geography.

'Prizes for geographical teaching in the great public schools were first awarded by the Society in 1869 and continued to be awarded till 1883. It is admitted that they had little or no influence in bringing about the object in view, the recognition of geography as a regular subject in the curriculum of our public schools.

'In addition to this, in 1876 silver medals were awarded in connection with the geography paper in the Oxford and Cambridge Local Examinations. These medals continue to be awarded; in these examinations geography occupies a really important place, and the number of candidates is very large.

'In 1882 the Council instituted prizes to be awarded for geography examinations to the cadets on board the training ships *Worcester* and *Conway*. These continue to be awarded, with satisfactory results.

'In 1884 the Society appointed Dr. Scott Keltie as an Inspector of geographical education for one year, and authorised him to make a collection of books and appliances used in teaching geography.

'The result of this action on the part of the Council was—(1) the appointment of a Reader in Geography at Oxford for five years, in February 1887, at a stipend of 300*l.*, to be paid half by the Society and half by the University. (2) The appointment in June 1888 of a Lecturer in Geography at Cambridge, to whose stipend the Society would contribute 150*l.* annually. As the Lecturer first appointed never entered on his office, a new Lecturer was appointed in May 1889, the Council agreeing to pay its contribution to his stipend for five years from the date of his appointment. This was renewed for five years in January 1893. (3) A contribution of 50*l.* annually by the Society towards Travelling Scholarships at Oxford and Cambridge for four years from June 1891. (4) A contribution of 60*l.* a year from 1886 to 1891 to the Oxford University Extension. (5) Contribution of 50*l.* a year for three years towards the stipend of a Lecturer on Geography at Owens College,

Manchester (1891); renewed for three years 1894. (6) 50*l.* a year for prizes to Training College Students. (7) 100*l.* a year for three years for lectures in London by Mr. Mackinder, and 50*l.* for a fourth year in connection with the London University Extension. (8) A memorial to the Gresham University Commissioners, urging the claims of geography in connection with the proposed Teaching University in London; the result being a statement in the Commissioners' Report that Geography should have a place in the first rank in the new University.

'The total sum spent by the Society in the last eleven years in the endeavour to improve geographical education in this country amounts to over 6,000*l.*

'The Council have in 1897 agreed to contribute largely to the support of the London School of Geography proposed by Mr. Mackinder.'

Royal Scottish Geographical Society.

'One of the objects for which the Royal Scottish Geographical Society was founded is stated as follows:—"To press for the recognition of geography as a branch of higher education, and to encourage its study in the Schools and Universities of Scotland by offering prizes or by other means."

'In pursuance of this object the Council, in June 1886, sanctioned a scheme for the encouragement and improvement of the teaching of geography in elementary Scottish schools by means of examinations and prizes; and through the courtesy of the Royal Geographical Society they obtained the loan of its collection of appliances used in geographical education, and exhibited them in the Museum of Science and Art, Edinburgh; they also arranged for a series of lectures on the teaching of geography, which were delivered at the same time in the Museum. The scheme of examinations and prizes was abandoned in 1891 in favour of courses of educational lectures for the benefit of teachers and others; and such courses have, with the exception of the year 1895–96, been delivered annually since January 1891.

'In October 1890 the Council, through its President, the Duke of Argyll, petitioned the Universities Commissioners to recognise the claims of geography as a department of higher education, urging that the subject should be included in every University preliminary or entrance examination, and that it should be accepted as one of the optional pass subjects qualifying for a degree in arts and in science; also that provision should be made for the systematic teaching of geography within the Universities, or within one or more of them, by the foundation either of professorships or of lectureships fully equipped with the necessary apparatus in maps, charts, globes, and models.

'The Council enumerated the beneficial results that would follow on the adoption of their recommendations, and gave an account of what was being done for the systematic study of geography in the Universities of other countries.

'In reply to the above petition the Council was informed, in January 1893, that by Ordinance No. 11 ("Regulations for Degrees in Arts") a knowledge of geography was required of every candidate for the preliminary examinations, and that a similar regulation affecting the preliminary examinations in science had been issued; it was also intimated that no lectureship had yet been founded, but that the University Courts had the power to institute them, though it seemed probable that the necessary funds would have to be raised by private benefaction.'

Manchester Geographical Society.

From its foundation the Manchester Geographical Society has done much to aid the spread of sound geographical knowledge in Lancashire, Cheshire, and Yorkshire by school examinations, popular lectures, and subscribing half the stipend of the lecturer in geography at the Owens College as long as there existed an independent lectureship in that subject.

The reports of the examination scheme are found in the volumes of the 'Journal.' A full account of the popular lecture scheme of the society was read at the Liverpool meeting of the British Association, 1896; an abstract is published in the Report, and the full paper, under the title of 'Practical Geography in Manchester,' is given in the 'Journal of the Manchester Geographical Society,' vol. xii. (1896), pp. 183–187.

Tyneside Geographical Society.

'We have made several attempts here to press the special study of geography in the local schools, both private and public, on some occasions offering prizes for examination, but have experienced great difficulty, owing to the apathy of teachers, who declare that the number of code subjects already in force is so great that they hesitate to voluntarily take up another special subject. We admit all teachers and pupils to our lectures at reduced charges—have even done it free, and they will not come.'

Liverpool Geographical Society.

'The Liverpool Geographical Society offers prizes for geographical knowledge, to be awarded on the results of an examination of the students at the Secondary Schools of Liverpool and district.'

The Climatology of Africa.—Sixth Report of a Committee, consisting of Mr. E. G. Ravenstein (*Chairman*), Sir John Kirk, Mr. G. J. Symons, Dr. H. R. Mill, *and* Mr. H. N. Dickson (*Secretary*). (*Drawn up by the Chairman.*)

Instruments.—Your Committee in the course of last year granted a set of instruments to Mr. G. W. Herdman, C.E., who until recently resided at Johannesburg, in the South African Republic. That gentleman, being at present engaged upon surveys in the Orange Free State, has been unable to make the observations desired by your Committee. He handed over his instruments to Mr. Hopwell J. S. Morrell, B.A. Oxon., who appeared to be well qualified for the work, but who has since left Johannesburg, taking the instruments with him. A fresh set of instruments has been ordered for Mr. Herdman, who has forwarded a draft for 10*l.* to defray its cost.

The Rev. Mr. Ormerod, of Golbanti, on the river Tana, has been granted a rain-gauge.

The Committee have likewise been requested by the Foreign Office to procure suitable sets of instruments for Nyasaland. This has been effected at a total cost of 66*l.* 8*s.* 10*d.*, for which two mercurial barometers, two maximum and two minimum thermometers, two hygrometers, twelve ordinary thermometers, and fourteen rain-gauges have been procured. The two sets

of instruments previously forwarded by the Committee to Nyasaland have been made over to her Majesty's Commissioner, subject to the condition that the observers to whom they have been granted shall be permitted to retain these instruments as long as they are willing to make good use of them, and send the results to the Committee.

All the above instruments were inspected by our Secretary before they were forwarded, and the usual Kew certificates have been obtained.

For this Foreign Office grant we are indebted to the interest taken in scientific work by the Right Hon. G. Curzon, and to the advocacy of the late Commissioner, Sir Harry Johnston.

Observations have been received from eighteen stations in Tropical Africa.

Nyasaland.—The supply of instruments recently forwarded will make it possible to equip a series of meteorological stations extending from Chinde, on the coast, to the southern end of Tanganyika. Mr. Alfred Sharpe, her Majesty's Acting Commissioner, and Mr. J. McClounie, the head of the scientific department of the Protectorate, take much interest in the work, and have promised to promote the objects of your Committee to the best of their power.

In the present report we are able to publish abstracts of two years' observations made by our old and valued correspondent, Mr. J. M. Moir, at Lauderdale. Mr. Moir is, after a holiday at home, about to return to Nyasaland; but his work has been continued during his absence by Mr. Thomson. We are also enabled, through the courtesy of Mr. A. Sharpe, to publish rainfall observations for ten stations. Earlier unpublished observations for Livingstonia have been added from the note-book of the late Mr. Stewart.

British East Africa.—The usual reports have only been received up to June last, and we therefore defer their publication until the reports for a full year shall have come to hand.

The Scottish missionaries at Kibwezi, to whom your Committee granted a set of instruments last year, have regularly sent in their registers since July last. They have been kept with much care, and include hourly observations for sixteen term-days, the first of the kind received from this protectorate.

A return of one year's rainfall at Mumia's, in Kavirondo, has been received from Mr. C. W. Hobley, who also forwards a few observations made with a Symons's earth-thermometer.

Uganda.—Through the kindness of the Foreign Office, we hope to be enabled to publish in our next report full meteorologieal records for a number of stations. In the meantime we present abstracts of fourteen months' observations on the variations in the level of the Victoria Nyanza, which have been made at three stations since January 1896.

Western Africa.—No observations whatever have been received from Bolobo, on the Congo, and Lambarene, on the Ogowai. From Warri (Benin) only one month's record has come to hand.

We have learnt with regret that the Rev. Bonzon, at Lambarene, is dead, and have taken steps to obtain his meteorological registers, and to recover the instruments which were lent him.

The abstracts published have been made by the Chairman of the Committee.

Your Committee have expended their grant. They propose that they be reappointed, and that a grant be made of 10*l*.

Nyasaland.

The following are the stations for which meteorological returns will be found in this report :—

Chiromo (16° 31′ S., 35° 10′ E., 300 ft.) on the Shire. At *Port Herald*, 27 miles lower down, 35 in. fell in 1893.

Chikwawa (16° 1′ S., 34° 56′ E., 350 ft.) on the Shire, at the foot of the road leading up to Blantyre.

Nyamteti Plantation, position uncertain, described as lying in the Cholo district, which is to the east of the road leading up to Blantyre. *Observer:* J. N. Cox.

Mandala (15° 48′ S., 35° 2′ E.), 1 mile to the south of Blantyre. In 1890 54·9 in. fell on 82 days (F. J. M. Moir). At Blantyre 50·8 in. fell in 1882, 52·9 in. in 1883, and 55·9 in. in 1886.

Zomba (15° 23′ S., 35° 20′ E., 2,970 ft.). In 1892 52·77 in. fell on 95 days, in 1893 38·06 in. on 79 days. At *Namitembe*, on the road to Mpimbi, on the Upper Shire, 82·32 in. fell in these two years (1892 and 1893) on 186 days.

Lauderdale Estate, Mlanje (16° 2′ S., 35° 36′ E., 2,580 ft.). The observations for 1896 were made by Mr. Thomson, those for previous years by Mr. J. W. Moir.

The 'Crater' is an old crater or a basin cut by the Mloza Stream. It lies 2 miles to the N.E. of Lauderdale, at an elevation of about 4,500 ft.

Nyasaland Coffee Company's Estate, Mlanje, 4 miles S.E. of Lauderdale.

Dunraven, a Mlanje plantation, 10 miles S.E. of Lauderdale, near Fort Anderson.

At *Fort Anderson* (16° 6′ S., 35° 43′ E.) 64·25 in. of rain fell on 164 days in 1893.

Fort Johnston (14° 40′ S., 35° 12′ E.) on the Upper Shire. The station of the African Lakes Company lies to the north, at the southern extremity of Lake Nyasa.

Livingstonia (14° S., 34° 45′ E., 1,570 ft.).

Likoma (12° S., 34° 40′ E., 1,570 ft.), a station of the Universities' Mission, on an island near the eastern shore of the lake. The rainfall is considerably less than on the western shore at Bandawe. In 1892–93 37·87 in. fell, as compared with 52·35 in. at Bandawe.

Bandawe (11° 55′ S., 34° 5′ E.). The observations in 1896 were made by Mr. R. S. Prentice. The mean annual rainfall for seven years amounts to 67·23 in. (ranging from 50·53 to 92·59 in.). Rain fell on an average on 74 days (57 to 126), but it seems that these earlier records were not quite complete, no account having been taken of the lesser rains which fell between May and September. At *Njuyu*, on the plateau to the west, the rainfall is much less. The annual fall for four years, for which we have synchronous records, amounted to 55·02 in. (on 67 days) at Bandawe, and to only 24·46 in. (on 41 days) at Njuyu.

Tanganyika Plateau. The rainfall is considerably less than near the lakes.

At *Maliwanda* the rainy season extends from November to April, and 36·19 in. fell in 1882–83 (Mr. Stewart's notebook).

At *Ikawa* 29·5 in. fell in 1895 (according to Mr. Dewar, of the Mwenzo Mission), and at *Fwambo* the mean for two years (1893–95) was 39·5 in.

Rainfall in Nyasaland, 1896.

—	Chiromo	Chikwawa	Cholo (Nyamteti Estate)		Mandala (Blantyre)	Zomba (Residency)	Mlanje		Fort Johnston		Likoma (Univ. Miss.)	Bandawe (Livingstonia Mission)	
							Lauderdale	Nyasaland Coffee Co.	Fort	African Lakes Company			
	In.	In.	In.	Days	In.	In.	In.	In.	In.	In.	In.	In.	Days
January	8·71	11·20	14·49	13	12·10	6·74	16·29	10·72	7·40	14·81	14·38	10·34	23
February	9·39	6·05	8·98	19	6·44	13·97	25·87	22·15	16·41	13·74	13·29	12·01	24
March	·96	4·28	6·38	16	12·56	13·52	16·00	13·10	1·83	3·82	9·93	24·20	22
April	1·48	1·10	2·78	5	1·49	1·51	17·54	7·65	5·76	4·95	5·76	14·66	19
May	1·05	·89	1·34	5	·90	·90	3·25	·00	·39	·00	·00	2·65	10
June	·00	·00	·00	—	·16	·00	·65	·00	·00	·00	·00	·00	—
July	·20	·25	2·99	3	·70	·27	4·45	2·40	·02	·00	·00	·00	—
August	·00	·15	1·77	3	·91	·36	2·13	·95	·09	·11	·10	4·55	3
September	·00	·00	·00	—	·00	·00	·00	·00	·00	·00	·00	·00	—
October	1·47	1·22	3·40	4	5·19	4·66	2·74	1·71	·81	·14	·00	2·35	1
November	3·38	·00	3·25	3	2·15	1·91	6·08	6·99	1·55	1·35	·96	5·33	6
December	8·30	3·64	9·88	10	9·40	19·50	13·16	12·87	7·94	6·82	6·16	16·50	18
Year 1896	34·39	28·78	51·26	81	52·00	63·34	108·15	78·54	42·20	45·74	50·58	92·59	126

Lauderdale, Mlanje. Lat. 16° 2′ *S., Long.* 35° 36′ *E.,* 2,580 *feet. Observer: John W. Moir.*

Month	Aneroid			Mean Temperature						Temp. Extremes		Mean Temp. Wet Bulb			Vapour Pressure			Dew Point			Relative Humidity			Rain			Cloud (0–10)		
	6 A.M.	Noon	6 P.M.	6 A.M.	Noon	6 P.M.	Max.	Min.	Mean	Highest	Lowest	6 A.M.	Noon	6 P.M.	6 A.M.	Noon	6 P.M.	6 A.M.	Noon	6 P.M.	6 A.M.	Noon	6 P.M.	Amount	Days	Heaviest Fall	6 A.M.	Noon	6 P.M.
1894	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	°	°	°	p.c.	p.c.	p.c.	In.		In.			
January	27·014	27·014	26·984	69·2	77·0	74·3	81·2	67·3	73·0	88·8	64·2	67·6	73·6	71·6	·656	·793	·746	66·8	72·4	70·6	92	86	88	19·10	28	3·31	7·1	—	—
February	27·030	27·021	26·994	69·5	78·3	74·3	81·7	68·1	73·4	85·8	64·2	67·0	74·7	72·2	·636	·822	·768	65·9	73·4	71·4	89	85	90	16·21	26	2·95	6·7	—	—
March	27·030	27·025	27·017	68·3	76·2	72·9	78·7	66·8	71·7	83·8	63·5	67·8	73·0	71·2	·674	·778	·745	67·6	71·8	70·5	98	86	92	14·99	28	2·40	8·0	—	—
April	27·129	27·122	27·104	64·4	73·0	69·6	75·6	63·0	68·1	84·9	58·5	63·3	69·4	67·8	·570	·681	·661	62·8	67·9	67·0	95	84	91	13·95	25	4·35	5·0	2·7	—
May	27·186	27·190	27·169	60·6	69·9	66·3	73·3	59·4	64·9	81·2	54·6	59·6	66·0	63·8	·500	·599	·566	59·0	64·2	62·5	95	81	88	3·56	18	1·87	4·3	1·6	—
June	27·232	27·272	27·242	57·7	68·3	63·7	71·2	56·1	62·2	75·1	52·1	55·3	62·1	59·8	·413	·495	·474	53·7	58·8	57·5	86	72	80	·77	12	·39	3·6	·7	—
July	27·271	27·259	27·249	57·4	70·3	64·1	72·6	56·4	62·6	79·7	51·7	55·8	63·8	60·3	·429	·526	·485	54·8	60·5	58·2	91	71	81	3·32	12	1·61	4·3	1·6	—
August	27·233	27·251	27·214	59·4	73·6	66·9	77·0	59·4	65·7	84·5	53·8	57·0	64·6	62·6	·441	·518	·524	55·5	60·1	60·4	87	63	80	·31	4	·14	2·3	·5	—
September	27·218	27·202	27·185	61·3	78·0	72·1	82·2	59·2	68·7	90·3	53·0	57·5	67·5	63·7	·435	·567	·505	55·2	62·6	59·3	81	59	65	4·39	10	2·12	1·8	1·2	—
October	27·116	27·122	27·092	67·8	87·9	81·0	92·5	65·6	76·7	100·1	60·5	62·9	73·9	69·5	·524	·695	·605	60·4	68·5	64·4	77	53	57	·26	4	·20	1·4	·2	—
November	27·171	27·226	27·166	69·8	85·4	81·2	89·6	68·3	77·2	97·4	65·0	66·5	72·7	70·9	·616	·675	·652	65·0	67·6	66·6	85	55	61	3·66	15	1·11	4·8	1·5	—
December	27·194	27·195	27·142	67·7	77·6	75·4	81·8	65·9	72·7	91·7	62·0	66·4	71·8	71·2	·634	·720	·720	65·8	69·5	69·5	93	77	82	23·91	19	6·88	3·9	1·8	—
Year 1894	27·151	27·158	27·130	64·4	76·3	71·7	79·8	62·9	69·7	100·1	51·7	62·2	69·4	67·0	·544	·657	·621	61·0	66·4	64·9	89	73	80	104·43	201	4·35	4·4	—	—

Lauderdale—continued.

Month	Aneroid			Mean Temperature						Temp. Extremes		Mean Temp. Wet Bulb			Vapour Pressure			Dew Point			Relative Humidity			Rain			Force of Wind (0–12)		
	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean	Highest	Lowest	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Amount	Days	Heaviest Fall	6 A.M.	2 P.M.	9 P.M.
1895	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	°	°	°	p.c.	p.c.	p.c.	In.		In.			
January	27·177	27·112	27·162	67·2	75·9	70·7	78·7	66·1	71·7	85·8	60·6	64·7	72·1	68·2	·586	·748	·663	63·5	70·6	67·1	88	84	89	38·34	28	12·41	1·2	2·0	1·4
February	27·177	27·135	27·175	69·2	77·7	71·4	81·4	68·2	73·6	87·0	63·3	66·4	73·5	68·8	·619	·782	·677	65·1	72·0	67·7	86	83	88	16·30	27	4·35	1·4	2·0	1·4
March	27·219	27·186	27·220	66·5	76·4	70·1	78·2	65·7	71·4	83·0	63·1	64·1	71·8	67·6	·573	·732	·649	62·9	70·0	66·5	88	80	88	13·07	26	1·74	1·4	1·8	1·7
April	27·267	27·232	27·286	63·3	74·3	67·8	76·4	62·9	68·9	80·8	58·0	60·7	69·0	64·6	·464	·654	·576	57·0	66·7	63·0	81	77	85	13·79	20	3·02	1·5	1·5	1·8
May	27·335	27·312	27·345	61·3	71·6	65·1	73·3	60·1	66·3	82·3	55·0	58·4	66·7	61·7	·460	·605	·515	56·7	64·4	59·9	85	78	83	6·18	15	1·17	1·2	1·6	1·5
June	27·391	27·382	27·413	57·8	67·4	61·1	69·0	57·1	62·5	73·4	54·1	54·2	61·9	57·4	·354	·498	·434	49·6	59·0	55·1	74	74	81	4·37	18	1·93	1·9	1·8	1·4
July	27·345	27·314	27·366	58·2	74·1	64·4	75·4	57·3	65·9	82·3	51·5	52·4	63·7	58·8	·336	·485	·439	48·1	58·2	55·4	69	58	73	·09	2	·05	1·5	1·2	1·6
August	27·319	27·276	27·339	58·1	73·1	65·1	74·8	57·4	65·7	82·1	52·6	54·4	63·6	58·2	·386	·492	·416	51·9	58·6	54·0	80	60	68	3·68	6	1·50	1·5	1·4	1·6
September	27·296	27·244	27·302	62·9	79·2	69·4	81·1	62·1	70·9	89·3	53·3	57·7	69·1	61·0	·424	·609	·452	54·5	64·6	56·2	74	61	63	3·11	7	2·30	1·6	1·7	2·2
October	27·267	27·211	27·248	65·9	81·9	72·3	84·6	64·4	73·8	92·9	55·4	62·0	69·4	65·1	·516	·592	·546	60·0	63·9	61·5	81	54	69	6·80	11	2·65	1·4	1·9	2·5
November	27·231	27·167	27·208	68·1	84·3	75·6	87·3	67·4	76·5	98·8	61·0	64·6	73·7	67·7	·574	·724	·588	63·0	69·7	63·7	84	61	66	10·73	12	3·75	0·7	1·3	2·3
December	27·162	27·091	27·153	68·9	78·2	71·4	81·2	67·7	73·5	89·1	63·1	66·9	73·1	68·6	·641	·762	·670	66·1	71·2	67·4	91	79	87	15·26	22	2·83	0·9	1·5	1·1
Year 1895	27·267	27·222	27·268	63·9	76·2	68·7	78·4	63·0	70·1	98·8	51·5	60·5	69·0	64·0	·494	·640	·552	58·4	65·7	61·5	82	71	78	131·72	194	12·41	1·4	1·6	1·7

LAUDERDALE—continued. *Direction and Force of Winds.*

1895	North 6 A.M. No.	North 6 A.M. Total Force	North 2 P.M. No.	North 2 P.M. Total Force	North 9 P.M. No.	North 9 P.M. Total Force	North-east 6 A.M. No.	North-east 6 A.M. Total Force	North-east 2 P.M. No.	North-east 2 P.M. Total Force	North-east 9 P.M. No.	North-east 9 P.M. Total Force	East 6 A.M. No.	East 6 A.M. Total Force	East 2 P.M. No.	East 2 P.M. Total Force	East 9 P.M. No.	East 9 P.M. Total Force
January	1	·5	1	2·0	—	—	—	—	—	—	—	—	1	1·0	—	—	2	2·0
February	2	2·5	2	2·0	1	·5	—	—	—	—	—	—	—	—	1	1·0	1	1·0
March	3	3·0	—	—	—	—	—	—	—	—	—	—	2	1·5	—	—	—	—
April	—	—	—	—	—	—	—	—	—	—	—	—	2	3·0	—	—	2	3·0
May	—	—	—	—	—	—	—	—	—	—	—	—	5	6·0	4	4·0	6	8·5
June	2	1·5	—	—	—	—	—	—	—	—	1	2·0	2	7·0	2	2·0	1	2·0
July	3	2·0	2	1·0	2	2·0	2	2·0	—	—	2	2·0	1	1·0	2	2·0	3	4·0
August	—	—	—	—	1	2·0	—	—	—	—	—	—	1	3·0	2	2·0	5	10·0
September	—	—	2	1·5	4	3·5	—	—	—	—	—	—	1	3·0	1	2·0	6	18·0
October	2	2·0	1	1·0	3	3·0	2	2·0	1	1·0	8	10·0	6	12·0	9	16·0	8	16·0
November	—	—	3	5·0	1	3·0	—	—	1	1·0	1	3·0	—	—	—	—	1	2·0
December	—	—	4	5·0	1	3·0	—	—	—	—	—	—	—	—	—	—	—	—
Year	13	12·5	15	17·5	13	17·0	4	4·0	2	2·0	12	17·0	21	37·5	21	29·0	35	66·5

1895	South-east 6 A.M. No.	South-east 6 A.M. Total Force	South-east 2 P.M. No.	South-east 2 P.M. Total Force	South-east 9 P.M. No.	South-east 9 P.M. Total Force	South 6 A.M. No.	South 6 A.M. Total Force	South 2 P.M. No.	South 2 P.M. Total Force	South 9 P.M. No.	South 9 P.M. Total Force
January	10	7·5	10	12·0	12	16·0	4	3·0	3	4·0	1	1·0
February	8	6·0	6	6·0	12	11·5	4	3·0	7	8·5	3	3·3
March	8	7·5	11	13·0	14	14·5	7	8·0	5	6·5	6	8·0
April	7	11·0	7	8·0	15	23·0	2	2·0	5	6·0	2	3·0
May	5	11·0	11	14·5	6	9·5	—	—	—	—	—	—
June	6	14·5	7	13·0	7	13·0	1	1·0	3	4·0	1	1·0
July	2	3·0	6	5·0	7	12·0	—	—	1	2·0	1	1·0
August	6	16·0	8	9·5	10	18·0	1	1·0	—	—	—	—
September	9	17·0	9	12·5	8	15·0	—	—	—	—	—	—
October	2	3·0	4	5·0	5	13·0	—	—	—	—	—	—
November	2	4·0	5	6·0	13	29·0	—	—	—	—	—	—
December	1	1·0	4	4·0	4	4·0	—	—	1	1·0	—	—
Year	66	101·5	88	108·5	113	178 5	19	18·0	25	32·0	14	17·3

1895	South-west 6 A.M. No.	South-west 6 A.M. Total Force	South-west 2 P.M. No.	South-west 2 P.M. Total Force	South-west 9 P.M. No.	South-west 9 P.M. Total Force	West 6 A.M. No.	West 6 A.M. Total Force	West 2 P.M. No.	West 2 P.M. Total Force	West 9 P.M. No.	West 9 P.M. Total Force
January	—	—	—	—	—	—	—	—	1	1·0	—	—
February	—	—	—	—	—	—	—	—	—	—	1	·5
March	—	—	—	—	—	—	—	—	1	1·0	—	—
April	—	—	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—	—	—
June	1	4·0	—	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	—	—	—
August	—	—	—	—	—	—	—	—	—	—	—	—
September	—	—	—	—	—	—	—	—	—	—	—	—
October	—	—	—	—	—	—	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—	—	—	—	—
December	—	—	—	—	—	—	—	—	2	6·0	—	—
Year	1	4·0	—	—	—	—	—	—	4	8·0	1	·5

1895	North-west 6 A.M. No.	North-west 6 A.M. Total Force	North-west 2 P.M. No.	North-west 2 P.M. Total Force	North-west 9 P.M. No.	North-west 9 P.M. Total Force	Calms 6 A.M.	Calms 2 P.M.	Calms 9 P.M.
January	2	2·0	2	1·5	1	1·0	12	5	14
February	1	2·0	3	2·0	1	1·0	10	2	9
March	2	2·0	1	·5	—	—	8	9	10
April	—	—	—	—	—	—	19	17	11
May	—	—	—	—	1	·5	18	15	15
June	2	1·5	—	—	—	—	17	12	20
July	—	—	—	—	—	—	20	18	16
August	—	—	1	·5	—	—	23	20	15
September	—	—	—	—	—	—	18	12	11
October	1	2·0	—	—	1	1·0	14	8	3
November	1	3·0	—	—	—	—	27	21	12
December	—	—	1	1·0	1	2·0	28	18	24
Year	9	12·5	8	5·5	5	5·5	214	157	160

For the whole series of observations, of which an abstract is given on pp. 412-14, we are indebted to the industry of Mr. John W. Moir.

The aneroid readings possess only a relative value, and are given as recorded. A new instrument came into use in November 1894.

The mean temperature is assumed to be $=\frac{1}{4}(6+6+\text{min.}+\text{max.})$.

The mean force of all the winds included in this table is only 1·3. The prevailing south-easterly winds exceed this force, being 1·5, whilst the force of the easterly winds is only 0·9, and that of the southerly winds 1·2.

Assuming these estimates to be correct, the south-easterly winds effect nearly 60 per cent. of the circulation of the air. They enter through the depression through which the trade route passes to Kiliman.

LAUDERDALE—continued. *Cloud and Prevalent Cloud-forms. Observer: J. W. Moir.*

1895	Cloud (0–10) 6 A.M.	Cloud (0–10) 2 P.M.	Cloud (0–10) 9 P.M.	6 A.M. Cirrus	6 A.M. Cumulus	6 A.M. Stratus	6 A.M. Nimbus	6 A.M. Cloudless	6 A.M. Mist	6 A.M. Haze	2 P.M. Cirrus	2 P.M. Cumulus	2 P.M. Stratus	2 P.M. Nimbus	2 P.M. Cloudless	2 P.M. Mist	2 P.M. Haze	9 P.M. Cirrus	9 P.M. Cumulus	9 P.M. Stratus	9 P.M. Nimbus	9 P.M. Cloudless	9 P.M. Mist	9 P.M. Haze
January	7·1	3·0	—	11	11	1	6	0	1	0	3	12	0	6	0	0	0	4	21	1	4	0	0	0
February	6·8	2·2	—	6	12	1	3	1	2	0	1	19	0	1	0	0	0	5	16	0	6	1	0	0
March	5·0	1·9	—	12	14	2	1	1	0	0	0	23	0	4	0	0	0	1	16	1	7	5	0	0
April	4 5	2·2	—	10	10	4	4	3	0	0	3	24	0	2	0	0	0	0	16	1	4	9	0	0
May	4·3	1·5	5·8	4	14	3	2	5	2	0	0	30	0	0	0	0	0	0	20	0	2	6	0	0
June	4·0	2·1	4·8	7	9	5	1	8	0	0	3	20	0	0	2	0	0	2	15	0	2	10	0	0
July	1·0	·0	3·0	3	2	8	0	17	0	0	5	8	0	0	13	0	0	1	8	0	0	22	0	0
August	3·2	·8	5·1	6	9	10	0	5	0	0	7	15	0	1	2	0	1	6	10	0	1	14	0	0
September	3·4	1·7	4·0	7	3	2	2	10	2	2	13	4	0	1	3	0	0	3	7	0	1	19	0	0
October	4·0	2·0	1·5	6	4	3	2	10	1	0	10	14	0	2	0	0	0	3	8	0	4	13	0	0
November	2·8	·8	3·3	9	5	6	1	9	0	0	2	25	0	1	0	0	0	3	19	0	1	5	0	0
December	8·2	2·8	5·4	14	9	6	0	0	0	0	4	23	0	1	0	0	0	5	23	0	1	2	0	0
Year	4·5	1·–	[5·1]	95	102	51	22	69	8	2	51	217	0	19	20	0	1	33	180	3	33	106	0	0

Crater, 1895 — *Chiperone*, 1895

1895	Crater Cloud (0–10) 6 A.M.	Crater 2 P.M.	Crater 9 P.M.	Chiperone Cloud (0–10) 6 A.M.	Chiperone 2 P.M.	Chiperone 9 P.M.
January	3·00	2·70	1·10	—	1·10	1·10
February	2·20	3·00	3·20	—	—	—
March	1·90	3·90	3·30	—	—	—
April	2·20	2·90	3·20	—	—	—
May	1·50	1·80	1·60	5·76	3·20	4·00
June	2·10	1·76	2·15	4·76	2·20	5·10
July	·03	·04	·00	3·00	0 08	·00
August	·08	·02	1·80	5·10	·02	2·70
September	1·70	·60	1·60	4·00	2·00	1·70
October	2·00	·40	1·20	1·50	·80	·70
November	·80	·80	·40	3·30	3·20	2·90
December	2·80	2·70	1·30	5·40	5·00	7·20
Year	1·69	1·22	1·74	—	—	—

Lauderdale, Mlanje. Observer: Mr. Thomson.

1896	Aneroid 6 A.M.	Aneroid 2 P.M.	Aneroid 9 P.M.	Mean Temperature max.	Mean Temperature n.
	In.	In.	In.	°	°
January	27·184	27·140	27·179	79·50	66·70
February	27·210	27·147	27·204	80·26	67·11
March	27·240	27·184	27·244	80·15	66·35
April	27·267	27·226	27·281	77·52	64·44
May	27·346	27·312	27·377	75·86	60·07
June	27·358	27·358	27·409	74·00	56·61
July	27·443	27·428	27·469	70·48	55·44
August	27·420	27·230	27·440	76·19	59·58
September	27·411	27·260	27·420	86·97	61·21
October	27·300	27·280	27·300	89·32	64·83
November	27·270	27·130	27·131	91·36	65·89
December	27·250	27·180	27·200	83·90	64·00
Year 1896	27·308	27·240	27·304	80·46	62·69
1895	27·265	27·222	27·268	78·45	63·02
1894	27·151	27·158	27·130	79·79	62·95

Dunraven, Mlanje. Communicated by Mr. Moir.

1894	Mean Temperature max.	Mean Temperature min.	Rainfall Amount	Rainfall Days	Rainfall Heaviest Fall
	°	°	In.		In.
January	—	—	12·63	20	2·35
February	—	—	13·34	20	2·75
March	—	—	14·33	23	2·17
April	72·0	62·8	12·34	21	3·57
May	73·0	59·8	1·51	8	·83
June	71·5	54·4	·51	4	·23
July	69·7	55·4	2·21	7	·72
August	78·0	59·0	·00	—	—
September	81·7	63·3	1·69	5	·95
October	89·8	70·0	·54	3	·50
November	—	—	8·29	11	2·08
December	83·8	70·0	14·99	16	5·80
Year 1894	—	—	82·39	138	—
January 1895	78·3	68·0	28·06	14	9·87

Livingstonia. Observer: Mr. Stewart.

Months	Aneroid (Means) 1876	Aneroid (Means) 1877	Mean Temperature 1876	Mean Temperature 1877	Rainfall 1876	Rainfall 1877
	In.	In.	°	°	In.	In.
January	28·12	28·22	78·0	78·0	12·18	8·86
February	28·24	28·41	79·5	80·5	13·75	11·85
March	28·33	28·35	80·0	82·0	—	2·99
April	28·33	28·32	77·5	80·0	—	·09
May	28·38	28·33	75·0	77·5	—	·00
June	28·50	28·42	69·5	74·0	—	·00
July	28·51	28·40	70·5	73·5	—	·90
August	28·47	28·38	73·5	74·5	—	·03
September	28·35	28·30	75·0	76·0	—	·00
October	28·28	28·30	77·5	80·0	—	·77
November	28·30	28·32	80·0	86·0	—	·00
December	28·41	28·30	82·0	85·5	—	8·34
Years	28·35	28·34	77·0	79·0	—	33·83

Dunraven.—The mean annual temperature is about 70° F., the daily range 13·8 F.

On January 15, 1895, 9·87 inches of rain fell, and on the following day (January 16) 7·58 inches.

Mr. Moir, at Lauderdale, recorded on these same days 12·41 and 9·04 inches, or a total of 21·45 for forty-eight hours, as compared with 17·45 inches at Dunraven.

Livingstonia.—These observations are recorded in a note-book of the late Mr. Stewart, C.E.

The aneroid means are said to be the means of the highest and lowest readings. They are printed here as they appear in the original MS.

The mean temperatures are deduced from the mean maximum and minimum temperatures.

Kibwezi. *Lat.* 2° 25 *S., Long.* 37° 55′ *E.,* 2,990 *feet.* *Observers: Rev. T. Watson, assisted by Matthew Wilson and John Paterson.*

1896	Pressure of Atmosphere			Mean Temperature						Temp. Extremes		Mean Temp.: Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain		
	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean	Highest	Lowest	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Amount	Days	Heaviest Fall
	In.	In.	In.	°	°	°	°	°	°	°	°				°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.		In.
July	27·079	27·014	27·054	60·7	78·8	67·1	84·3	55·2	68·4	91·5	50·0	58·4	65·0	61·3	57·0	57·8	58·1	·465	·478	·483	88	49	73	·004	—	·003
August	27·057	26·989	27·036	61·4	79·8	67·1	84·8	55·9	68·8	91·0	49·7	59·5	65·7	61·8	58·4	58·5	59·0	·489	·490	·498	90	48	76	·14	2	·09
September	27·015	26·929	26·981	62·1	86·4	69·9	91·5	57·0	72·1	96·0	51·0	59·0	68·4	63·0	57·2	59·8	59·4	·468	·513	·506	84	41	70	·10	2	·07
October	27·007	26·904	26·958	66·2	88·5	73·3	93·6	61·9	75·3	97·7	54·0	64·2	70·6	66·0	63·2	62·6	62·0	·579	·568	·555	90	42	67	·53	4	·32
November	26·912	26·875	26·908	67·2	79·1	68·7	83·5	64·1	70·9	89·7	61·2	66·5	71·1	67·3	66·2	67·8	66·7	·642	·680	·653	97	68	93	8·60	26	1·40
December	26·944	26·891	26·930	67·7	80·3	67·2	84·8	63·1	70·6	87·7	56·5	67·3	72·6	66·2	67·1	69·6	65·8	·663	·722	·633	98	70	95	4·55	15	1·08

The barometrical observations have been reduced to 32° F., and to Lat. 45°.
The mean temperature is assumed to be $= \frac{1}{4}(7+2+9+9)$. The mean for the six months is 71°·0. A mean deduced from $\frac{1}{2}$ (max.+min.) would be 73°·30, or 2°·3 too high.

According to the local authorities the rainfall at Mumia's in 1896 was far below the average.

Nearly the whole of the rainfall took place between 2 and 7 P.M.

The rain was nearly always accompanied by thunder.

Most of the rain occurs with an easterly wind blowing from the highlands in the direction of the lake.

The rain-gauge was by Casella, 8 inches in diameter, and had been procured through the Meteorological Office (M.O. 364).

Earth Temperatures.—At *Mumia's* on March 1, 1897, at 5.30 P.M., Mr. Hobley lowered one of Symons's earth thermometers to a depth of 3 feet below the surface, the temperature of the air at the time being 71° F., and that of the earth thermometer 72°. On March 3, 1897, at 5 P.M., the air temperature being 72° F., the earth thermometer was withdrawn, and was found to indicate a temperature of 77° F.

A similar experiment was made at *Mongichi's*, on the southern slope of Mount Elgon, at an elevation of 5,000 feet, when the earth temperature, at a depth of 3 feet, was found to be 71° F.

[The result obtained at Mongichi's approximates the mean temperature of the year; that at Mumia's is clearly too high. We are promised a systematic series of these earth temperatures.]

Mumia's, Kavirondo. *Lat.* 0° 20′ *N., Long.* 34° 30′ *E.,* 4,000 *feet.* *Observer: C. W. Hobley, Mem. Inst. C.E.*

1896–97	Rainfall		
	Amount	Days	Heaviest Fall in 24 Hours
	Inch		Inch
February 1896	·79	3	·45
March	4·18	11	1·32
April	3·96	16	1·36
May	7·29	15	2·71
June	6·14	18	1·58
July	6·70	17	1·40
August	6·67	20	1·22
September	5·13	19	1·66
October	4·61	17	1·02
November	8·13	21	1·36
December	1·63	6	·67
January 1897	3·53	10	1·02
Totals	58·76	173	—

Kibwezi. *Lat.* 2° 25′ *S., Long.* 37° 55′ *E.,* 2,990 *feet.*

1896	Rainfall		
	Amount	Days	Heaviest Fall
	Inch		Inch
January	·93	5	·45
February	1·79	4	1·63
March	1·87	7	·82
April	2·81	11	1·06
May	·35	4	·17
June	·01	1	·01
July	·004	—	·003
August	·14	2	·09
September	·10	2	·07
October	·53	4	·32
November	8·60	26	1·40
December	4·55	15	1·08
Year 1896	21·68	81	1·63
1895	33·11	90	2·68
1894	26·73	44	3·34

Kibwezi: Means of Hourly Observations, July to December 1896.

Hours	July 11 and 21 Barometer	Thermometer Dry	Thermometer Wet	Vapour Pressure	Relative Humidity	August 1, 11, and 21 Barometer	Thermometer Dry	Thermometer Wet	Vapour Pressure	Relative Humidity	September 1, 11, and 21 Barometer	Thermometer Dry	Thermometer Wet	Vapour Pressure	Relative Humidity
	In.	°	°	In.	p.c.	In.	°	°	In.	p.c.	In.	°	°	In.	p.c.
Midnight	27·118	60·7	58·4	·465	87	27·056	64·7	62·3	·537	88	27·026	61·2	58·1	·452	84
1 A.M.	27·085	59·4	57·2	·446	88	27·096	64·5	62·0	·530	87	27·008	59·2	56·7	·435	87
2 A.M.	27·074	57·9	56·4	·440	90	27·039	64·3	62·0	·532	88	26·993	57·5	55·3	·415	88
3 A.M.	27·085	57·4	55·7	·426	90	27·034	64·0	61·7	·526	88	26·991	57·4	54·9	·406	86
4 A.M.	27·093	56·0	54·6	·412	92	27·049	63·1	61·8	·538	93	26·991	55·5	53·7	·394	90
5 A.M.	27·099	55·5	54·4	·412	93	27·043	62·5	61·2	·526	93	27·018	54·1	52·6	·381	91
6 A.M.	27·088	55·2	54·2	·410	93	27·041	61·6	60·2	·507	92	27·009	53·2	51·7	·368	91
7 A.M.	27·104	61·0	58·7	·471	87	27·058	63·0	61·3	·524	92	27·031	58·9	54·0	·368	74
8 A.M.	27·129	63·9	61·0	·507	85	27·093	66·5	63·2	·546	84	27·052	70·1	62·6	·492	67
9 A.M.	27·137	72·7	64·6	·527	66	27·083	69·8	64·0	·541	74	27·052	75·2	64·7	·505	58
10 A.M.	27·135	74·5	63·7	·481	56	27·082	72·2	64·7	·535	68	27·045	80·7	65·3	·469	45
11 A.M.	27·125	77·9	64·9	·484	51	27·069	73·5	64·7	·522	63	27·028	82·2	65·3	·454	41
Noon	27·108	78·7	65·5	·495	50	27·042	74·3	65·2	·468	55	26·997	86·2	67·4	·482	38
1 P.M.	27·082	77·2	64·0	·463	49	27·018	75·2	64·9	·511	59	26·980	87·5	67·7	·479	36
2 P.M.	27·068	76·9	63·7	·457	49	26·994	75·5	65·1	·514	59	26·931	88·0	67·4	·464	35
3 P.M.	27·058	76·5	64·0	·469	51	26·981	76·6	65·5	·516	57	26·917	86·5	67·2	·472	37
4 P.M.	27·053	76·0	63·5	·460	52	26·990	75·7	64·9	·506	57	26·912	84·7	67·2	·490	41
5 P.M.	27·061	74·9	63·4	·468	55	26·977	73·8	64·5	·513	62	26·940	81·8	65·2	·455	42
6 P.M.	27·066	72·9	63·4	·488	60	26·986	71·9	63·7	·507	65	26·949	77·5	63·6	·448	48
7 P.M.	27·077	71·6	62·2	·465	60	27·002	69·1	63·3	·523	73	26·957	73·9	62·8	·460	55
8 P.M.	27·098	70·2	61·5	·458	60	27·032	67·1	62·1	·507	74	26·964	71·2	62·6	·481	63
9 P.M.	27·107	68·5	61·5	·475	67	27·048	66·2	61·5	·498	77	27·003	68·7	61·6	·476	68
10 P.M.	27·137	66·5	61·5	·495	76	27·053	65·7	61·6	·506	80	27·014	66·1	61·1	·488	77
11 P.M.	27·139	64·9	61·0	·497	81	27·067	64·9	61·4	·508	82	27·014	64·7	60·9	·496	81
Mean	27·097	67·8	60·8	·465	70	27·038	68·6	63·0	·518	75	26·993	70·9	61·2	·450	63

Hours	October 1, 11, and 21 Barometer	Thermometer Dry	Thermometer Wet	Vapour Pressure	Relative Humidity	November 1, 11, and 21 Barometer	Thermometer Dry	Thermometer Wet	Vapour Pressure	Relative Humidity	December 1 and 11 Barometer	Thermometer Dry	Thermometer Wet	Vapour Pressure	Relative Humidity
	In.	°	°	In.	°	In.	°	°	In.	p.c.	In.	°	°	In.	p.c.
Midnight	27·013	66·7	63·7	·559	86	26·919	68·5	67·5	·662	95	26·883	66·7	66·5	·647	99
1 A.M.	26·912	65·4	62·9	·548	87	26·913	67·6	66·6	·641	96	26·888	66·9	66·5	·645	98
2 A.M.	26·965	64·2	62·1	·536	89	26·907	67·3	66·3	·635	95	26·888	66·5	66·5	·649	100
3 A.M.	26·970	62·4	61·3	·530	94	26·904	66·6	66·0	·632	97	26·888	66·4	66·4	·649	100
4 A.M.	26·985	62·5	60·9	·518	91	26·905	66·1	65·5	·621	97	26·889	66·6	66·5	·648	99
5 A.M.	26·992	62·2	60·5	·509	91	26·909	66·3	65·7	·625	97	26·889	66·5	66·5	·649	100
6 A.M.	27·000	61·7	60·2	·506	92	26·917	66·3	65·6	·622	97	26·889	66·0	66·0	·638	100
7 A.M.	27·008	64·7	62·3	·537	88	26·927	67·9	66·8	·645	95	26·891	67·0	66·9	·657	99
8 A.M.	27·019	70·5	65·7	·583	78	26·947	70·3	67·8	·654	89	26·891	69·5	68·2	·677	94
9 A.M.	27·032	75·0	66·9	·577	66	26·947	75·0	69·2	·654	75	26·889	70·2	68·5	·678	92
10 A.M.	27·018	80·1	67·1	·533	52	26·942	77·6	70·3	·666	70	26·888	73·1	70·2	·709	87
11 A.M.	26·992	85·2	70·6	·601	49	26·915	78·5	70·3	·657	67	26·885	76·7	72·0	·736	80
Noon	26·956	86·6	70·2	·573	45	26·910	80·1	70·7	·656	64	26·883	76·5	71·0	·702	77
1 P.M.	26·924	88·3	70·6	·570	43	26·890	80·0	70·7	·657	65	26·883	72·3	68·7	·666	83
2 P.M.	26·903	88·8	70·7	·569	42	26·868	80·5	71·6	·684	66	26·881	75·5	70·4	·690	78
3 P.M.	26·883	87·7	69·4	·534	42	26·860	80·8	69·7	·614	58	26·883	76·0	70·7	·699	77
4 P.M.	26·871	86·7	68·8	·524	42	26·879	76·4	69·7	·658	72	26·883	75·0	71·1	·721	83
5 P.M.	26·893	84·2	67·7	·512	43	26·874	74·8	69·2	·656	76	26·882	74·1	71·0	·726	86
6 P.M.	26·892	80·2	66·7	·519	51	26·887	70·7	68·0	·657	87	26·883	71·9	70·4	·726	91
7 P.M.	26·911	77·1	66·4	·540	58	26·897	69·3	68·2	·677	95	26·900	69·5	68·2	·677	94
8 P.M.	26·942	75·2	65·2	·521	60	26·913	68·2	67·0	·649	94	26·905	68·1	67·4	·661	97
9 P.M.	26·953	72·7	65·3	·549	68	26·927	67·9	66·8	·645	95	26·916	67·5	66·7	·648	97
10 P.M.	26·986	70·5	65·2	·567	76	26·930	67·4	66·3	·634	95	26·918	66·7	66·2	·639	98
11 P.M.	26·988	69·5	64·4	·553	77	26·927	67·7	66·6	·640	95	26·923	67·0	65·9	·624	95
Mean	26·960	74·5	65·6	·544	67	26·909	71·7	68·0	·648	84	26·891	70·1	68·3	·673	92

Kibwezi.—The instruments used since July are those supplied by the Committee of the British Association. The barometer observations have been reduced to 32° F. and to 45° N. lat., but not to the sea level. Vapour pressure, dew point, and relative humidity have been computed from Tables 40 to 42 in the 'Smithsonian Meteorological Tables,' 5th edit., 1893.

Variations in the Level of Victoria Nyanza.

Decades 1896	Lake Level: Port Alice	Lake Level: Lubwa	Lake Level: Port Victoria	Rain: Port Alice Amt.	Rain: Port Alice Days	Rain: Port Victoria Days
	In.	In.	In.	In.		
January, I.	7·8	—	6·9	—	—	—
II.	7·1	—	6·7	—	—	—
III.	6·1	—	6·3	—	—	—
February, I.	5·7	4·4	5·9	—	—	—
II.	4·6	3·3	4·3	—	—	—
III.	2·9	2·5	3·6	—	—	—
March, I.	1·9	2·2	2·8	—	—	—
II.	1·1	3·3	3·5	—	—	—
III.	2·2	3·2	3·4	—	—	—
April, I.	2·7	2·3	2·2	15·40	4	—
II.	3·2	3·9	3·4	3·90	8	—
III.	3·9	3·4	3·4	3·17	6	—
May, I.	3·5	3·0	3·4	·85	6	—
II.	2·9	4·2	3·3	2·33	4	—
III.	2·5	3·7	2·8	1·27	5	—
June, I.	1·1	2·9	2·4	2·46	5	—
II.	1·2	2·2	2·5	·26	1	—
III.	2·1	2·3	2·1	·46	2	—
July, I.	2·2	1·2	1·2	·08	2	2
II.	·7	− ·2	− ·1	·20	2	0
III.	·0	−1·2	−1·7	·03	1	0
August, I.	− 0·6	−2·1	−2·3	2·04	6	5
II.	− 1·0	− ·8	−2·4	2·06	6	3
III.	− 1·3	−1·5	−2·0	·00	—	0
September, I.	− 3·8	−2·8	−4·1	·20	2	2
II.	− 5·1	−4·1	−5·2	·87	2	5
III.	− 5·9	−6·1	−6·7	1·30	1	0
October, I.	− 7·5	−7·0	−7·3	·38	2	0
II.	−10·0	−8·7	−8·8	1·34	3	2
III.	− 9·8	−8·8	−9·7	2·87	6	6
November, I.	− 8·6	−8·7	−7·6	3·66	10	9
II.	− 4·4	−4·2	−2·7	7·21	8	6
III.	− 2·3	−1·7	−1·0	1·18	7	2
December, I.	− 0·9	−2·3	−1·7	3·46	4	2
II.	− 2·1	−2·2	−2·7	·97	3	0
III.	− 2·2	−3·4	−2·4	·21	3	0
Year (Mean) .	0·0	0·0	0·0	—	—	—
1897 January, I.	− 3·0	−3·5	−3·5	·08	2	1
II.	− 2·7	−2·5	−2·1	·47	2	5
III.	− 1·9	−2·6	−1·9	1·20	2	0
February, I.	− 3·0	−1·50	−1·55	1·21	7	6
II.	− 2·0	−0·80	− ·17	·59	3	2
III.	− 1·7	−1·96	− ·44	1·82	3	1

Months	Mean Lake Level: Port Alice	Mean Lake Level: Lubwa	Mean Lake Level: Port Victoria	Fluctuations: Port Alice	Fluctuations: Lubwa	Fluctuations: Port Victoria	Rain Fall Port Alice: In.	Rain Fall Port Alice: days
1896	In.	In.	In.	In.	In.	In.	In.	days
January . .	7·1	5·6	6·6	3·0	2·5	3·7	—	4
February . .	4·4	3·5	4·4	3·0	5·5	5·5	—	—
March . .	2·2	2·9	3·3	3·5	5·6	6·7	—	—
April . .	3·1	3·2	3·0	2·0	5·7	3·5	8·61	18
May . . .	3·0	3·7	3·2	2·0	5·0	2·0	4·45	15
June . .	1·5	2·5	2·4	2·0	2·7	4·0	3·18	8
July . .	0·9	−0·1	−0·2	3·0	5·0	4·0	0·31	5
August . .	−1·0	−1·5	−2·2	2·0	3·0	3·0	4·10	12
September .	−4·9	−4·3	−5·3	4·5	6·2	5·0	2·37	5
October . .	−8·4	−8·2	−8·6	4·0	5·5	3·5	4·59	11
November .	−5·1	−4·8	−3·7	7·7	10·5	8·5	12·05	25
December .	−1·8	−2·6	−2·3	2·7	4·2	3·0	4·69	10
Year (Mean) .	0·0	0·0	0·0	3·3	5·1	4·4	—	—
1897 January . .	−2·0	−2·8	−2·5	2·5	2·5	2·75	1·75	5
February .	−2·2	−1·0	−0·7	2·0	4·0	3·00	2·62	13

Notes.

The observations on the rise and fall of the level of Victoria Nyanza were begun in January 1896 by direction of Sir Ernest J. L. Berkeley, H.M.'s Commissioner, who placed this work under the charge of Mr. R. J. D. Macallister. There are at present three stations:—

Port Alice, or *Ntebe*, the Lake Port of the capital. The observations are made daily at noon. The observers were Major A. E. Smith (January), Mr. Alex. Geo. Boyle (February to September), and Mr. Fred. Pordage.

Lubwa, near the outlet of the Victoria Nile. Observer, up to the beginning of February 1897, Mr. W. Grant.

Port Victoria, on Berkeley Gulf, in the N.E. corner of the lake. Observer, up to the end of 1896, Mr. R. J. D. Macallister; since that time Mr. C. W. Fowler.

At Lubwa and Port Victoria the observations are made at 9.30 A.M. Observations on the rainfall are made at Port Alice only, no gauges being available.

Care has been taken, when fixing the gauges, to prevent a subsequent settlement.

On beginning their work the observers were of necessity compelled to choose an arbitrary datum level. In our abstract the datum level accepted is the mean level of the lake during 1896.

In the accompanying tables the results are given by decades, and also by months.

In examining this interesting record it will be found that the influence of the *rainfall* upon the level of the lake is not so immediately apparent as might have been expected. Thus, a rainfall of 2·36 in. on November 14, 1896, only caused a rise of the lake to the extent of 0·75 in., and the heavy rains during October and November (16·64 in.) influenced the lake level to the extent of only about 5 in. Evaporation, no doubt, as also the irregular distribution of the rains over a lake covering an area of 25,000 sq. miles, go far to explain this.

The *winds* exercise a decided influence upon the level. They are regular land and lake breezes, blowing off-shore (from the E. or N.E.) in the morning, and changing about noon to W. or S.W. The lake breezes are more especially important, and Mr. Macallister remarks that a strong S.W. breeze will cause a rise in the level of the lake to the extent of from 1 to 3 in.

As the observations at two of the stations are made in the morning the actual mean level is probably a little higher than it is made to appear from our abstract. In order to trace the influence of the wind upon the lake level it would be necessary to establish a self-registering gauge or to make observations at least thrice daily.

Taking the mean of the three stations we find that on January 1 the level stood 7·8 in. above the datum, whilst on December 31 it was 3·3 in. below it, a difference of 11·1 in. The level was highest in the beginning of the years, lowest (−9·2 in.) during the 2nd decade of October. The extreme range amounted to 18·2 in. (Port Alice 19·0 in., Lubwa 17·5 in., Port Victoria 18·2 in.)

It is desirable that similar observations should be made on the S., E., and W. shores of the lake. The connection of these stations by lines of spirit levelling can hardly be looked for for many years to come.

Experiments on the Condensation of Steam. *By* H. L. CALLENDAR, *M.A., F.R.S., Professor of Physics, and* J. T. NICOLSON, *B.Sc., Professor of Mechanical Engineering, McGill University, Montreal.*

[Ordered by the General Committee to be printed *in extenso.*]

PART I.—*A New Apparatus for Studying the Rate of Condensation of Steam on a Metal Surface at Different Temperatures and Pressures. By* Professor H. L. CALLENDAR, *and* Professor J. T. NICOLSON.

As the result of some experiments by electrical methods on the measurement of the temperature changes of the walls and steam in the cylinder of a working steam-engine, which were made at the McDonald Engineering Building of McGill University in the summer of 1895, the authors arrived at the conclusion that the well-known phenomena of cylinder condensation could be explained, and the amount of condensation in many cases predicted from a knowledge of the indicator card, on the hypothesis that the rate of condensation of steam, though very great, was not infinite, but finite and measurable. An account of these experiments was communicated to the Institution of Civil Engineers in September 1896, and will, it is hoped, be published in the course of the ensuing session. In the meantime, the authors have endeavoured to measure the rate of condensation of steam under different conditions by a new and entirely different method, with a view to verify the results of their previous work, and also to estimate the influence, if any, of the film of water adhering to the walls of the cylinder.

In considering the condensation of steam on a metal surface, it is usually assumed that the surface exposed to the steam is raised up to the saturation temperature corresponding to the pressure of the steam, and that the amount of condensation is limited by the resistance of the water-films to the passage of heat from the steam to the metal and from the metal to the water. If the steam contains air, there may also be a considerable resistance due to the accumulation of a film of air on the surface, but it is comparatively easy to exclude this possibility in experimental work.

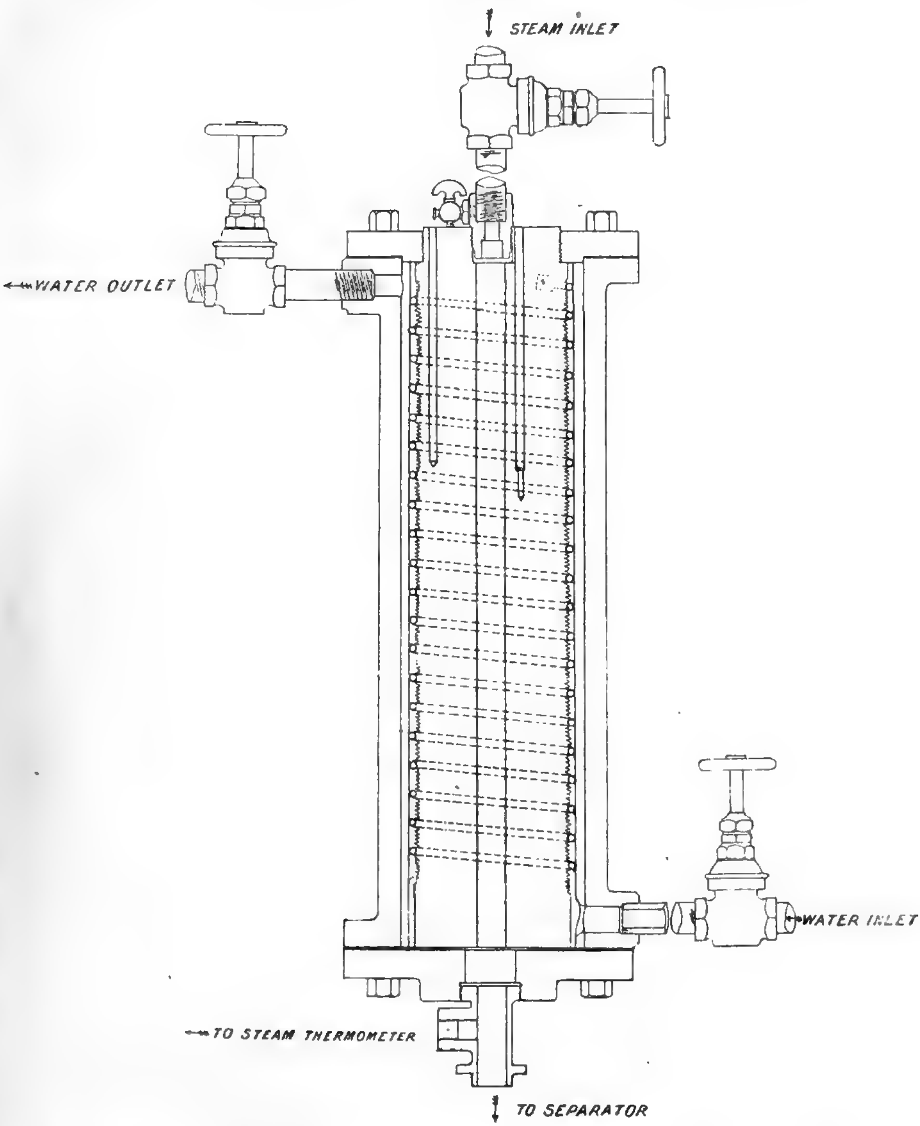
In the steam-engine experiments above referred to, it was practically certain that the water-film due to the cyclical condensation never exceeded one-thousandth of an inch in thickness, and that the resistance offered by it was unimportant. At the same time, it appeared clear that the temperature of the surface of the metal at its highest was considerably below the saturation temperature of the steam, a condition which could only be explained by supposing the rate of condensation of steam on a surface to be limited by some physical property of steam itself, apart from the resistance of the condensed film of water. Interpreted in this manner, the experiments led at once to the conclusion that the rate of condensation at any moment was simply proportional to the difference of temperature between the saturated steam and the surface on which it was condensing.

The limit thus found was shown to be capable of explaining many of the phenomena of cylinder condensation in a rational manner, but the method by which it was established was of an indirect and somewhat intricate character, and appeared to require some simpler and more direct confirmation.

If the rate of condensation of steam were really infinite, it should be

possible, by a suitable modification of the surface-condenser method, to obtain values of the condensation considerably in excess of those given by the formula deduced from the temperature cycle observations.

To accomplish this, it is necessary to eliminate as completely as possible the resistance to the passage of heat of the water-films between the steam and the metal, and between the metal and the circulating water, and at



the same time to measure as accurately as possible the temperature of the metal.

These considerations led to the form of apparatus shown in the figure. The resistance to the passage of heat from the metal to the condensing water in this apparatus is practically eliminated by employing a thick cylinder, 5 in. diameter and 2 ft. long, with a screw thread cut on its outer surface. Water from the high-pressure mains is forced to circulate round this surface with a very high velocity, in the narrow space between the

cylinder and the surrounding tube. In this manner it is possible to obtain a very uniform temperature for the external surface, differing but little from that of the circulating water.

If the cylinder is made sufficiently thick, its temperature may be approximately determined at any depth by inserting mercury thermometers. It was intended at first to use thermo-couples for this purpose, but the apparatus in this form would have been unsuitable for students' use in the ordinary course of laboratory work, which was one of the primary objects in view in the construction. It would also have been desirable to make the cylinder of copper, which would have reduced the resistance of the metal to the lowest point. The authors were compelled, however, to content themselves for the time with cylinders of cast iron and of mild steel.

The internal surface of the cylinder, upon which the steam was condensed, was a hole one inch in diameter, drilled in the solid metal. In order as far as possible to minimise the resistance of the surface film of condensed water, a revolving brush was constructed of very thin strips of steel to wipe the surface five or six times a second. This wiper was found to wear in a very short time to so perfect a fit, and the water-film must have been so energetically stirred, that its resistance to the passage of heat must have been far less than that of the best conducting metal.

Under these conditions, if the rate of condensation of steam were infinite it should have been possible to obtain a rate of condensation many times greater than the limit deduced from the cylinder condensation experiments above mentioned.

On making the experiment, however, it was found that the wiper made very little difference to the amount of condensation. With the wiper revolving at the rate of 160 per minute, the condensation was increased by about 5 per cent. on the average of several experiments. It may be concluded from this that the drops of condensed water with which the surface is partially covered are in such rapid motion that they do not appreciably obstruct the passage of heat from the steam to the metal. A film of the same average thickness, if it were absolutely quiescent, and if its conductivity, as generally estimated, were only one-hundredth of that of cast iron, would no doubt prove a serious obstacle, but, as a matter of fact, the viscosity of water at these temperatures is so small, and the motion so rapid, that the drops cannot be treated as a quiescent film.

The temperature at various distances from the inner surface of the cylinder was determined by means of mercury thermometers inserted to a depth of 8 or 9 inches in holes drilled parallel to the axis. From the temperatures so observed, the conductivity of the metal and the temperatures of its inner and outer surfaces could be approximately inferred. It was found, however, that the presence of the holes interfered materially with the flow of heat through the metal, and that the readings of the thermometers under these conditions were not altogether trustworthy.

From a number of observations on the cast-iron cylinder, a conductivity of 5·3 thermal units (pound degree) Fahr. per square foot per minute was deduced for a gradient of one degree F. per inch; a result which agrees very closely with the authors' previous determination by a different method. For the steel cylinder a conductivity of 5·8 was similarly deduced. These results apply to a mean temperature of about 140° F., and are much lower than the values generally assumed for iron.

In order to verify the authors' previous result as to the rate of

condensation of steam, the temperature of the inner surface of the metal was calculated on the assumption of a rate of condensation equivalent to 0·74 T.U.F. per second per square foot per degree F. difference of temperature. The values so found agreed with the observed temperatures within the limits of error of the observations. Owing to the inferior conductivity of the iron, the test was not altogether satisfactory, as the difference of temperature between the steam and the surface rarely amounted to as much as 30 degrees. With a cylinder of pure copper, and using thermo-couples for determining the temperature at a given depth, it should be possible to obtain a more certain confirmation by this method.

In performing the experiments, a number of variations in points of detail were introduced from time to time. The flow of the circulating water was varied in velocity, and directed in different ways. In order to secure uniformity in the distribution of temperature measured in different directions from the centre, the spiral circulation was found to be essential. In the second apparatus, the screw thread was at first replaced by a baffle plate, which was intended to direct the water into a spiral course, but the results found were unsatisfactory.

In some cases steam was admitted from the top of the apparatus, and in other cases from the bottom. With the steam supply at the bottom, it was found that the condensed water refused to drain down the vertical 1 inch tube in opposition to the current of steam, although the maximum velocity of the steam could not have exceeded 10 feet per second.

The following set of observations, each of which represents the mean of several taken on different days under similar conditions, will sufficiently indicate the general nature of the results.

Condensation Results Summary. Mild Steel Bar. Wiper Removed.

Condensation T.U. per sq. ft. sec.	Steam Temp. Obs.	Surface Temp. Calc.	Difference Steam and Surface	Temperature in Metal at Distances 1 in. Calc.	1 in. Obs.	1·5 in. Calc.	1·5 in. Obs.	2 in. Obs.	Conductivity K
20·0	330°	303°	27°	208°	214°	154°	152°	113°	5·84
17·2	300°	277°	23°	193°	198°	143°	142°	109°	5·66
15·4	274°	253°	21°	179°	184°	136°	134°	105°	5·81

The temperatures of the metal at distances of 1 inch, 1·5 inch, and 2 inches, from the axis of the bar, were observed by means of mercury thermometers which were very carefully centred by small iron washers in holes filled with mercury. The hole fitting the bulb of the 1 inch thermometer was $\frac{3}{16}$ inch in diameter. The other holes were $\frac{5}{16}$ inch.

It will be observed that in this particular set of experiments, the temperatures at 1 inch in the metal, when calculated to agree with the assumed rate of condensation, are all too low as compared with those observed, whereas the temperatures similarly calculated at 1·5 inch are all too high. This might at first sight appear to indicate a very rapid diminution of the conductivity with rise of temperature, but, after making various tests, the effect was traced partly to the disturbance of the heat flow caused by the presence of the holes, and partly to differences of density of the bar in directions at right angles. The latter differences were not observable in the case of the cast iron.

The observations taken at different pressures do not indicate any marked difference in the rate of condensation per degree-second. These results, so far as they go, are in agreement with the authors' previous work, but they hope to be able to obtain more conclusive evidence.

PART II.—*An Electrical Method of Measuring the Temperature of a Metal Surface on which Steam is Condensing.* *By* H. L. CALLENDAR, *M.A., F.R.S., Professor of Physics, McGill University, Montreal.*

The object of the following experiments, which were made at the McDonald Physics Building with a different apparatus, was the measurement of the temperature of the metal surface itself by a more direct and accurate method. It was also desired to verify as exactly as possible whether the rate of condensation of steam at atmospheric pressure were the same as at the higher temperatures and pressures at which most of the preceding experiments were made.

The condenser used for these experiments was a very thin platinum tube, a quarter of an inch in diameter and sixteen inches long. The thickness of the tube was only six-thousandths of an inch, and the greatest difference of temperature between its inner and outer surfaces at the maximum rate of condensation observed in the experiments could not have been greater than a quarter of a degree Centigrade.

The mean temperature of the metal itself was determined in each case by measuring the electrical resistance of that portion of the tube on which the steam was condensing. The author has had considerable experience in the application of this method, which, moreover, is very easily applied if suitable apparatus is available.

The platinum tube was enclosed in an outer tube of brass or glass, and steam was admitted to the space between the two tubes. A steady current of condensing water was maintained through the platinum tube. The amount of condensation could be inferred by measuring the flow of water, and observing the difference of temperature between the inflow and the outflow. In many cases the condensed water was also measured. Applying a small correction for radiation, the two methods always agreed within one-half of one per cent. The pressure of the steam in the outer tube, which was never far from the atmospheric, was observed by means of a mercury column.

The conditions of the experiment as to flow of water and steam, size and length of the external tube, &c., could be varied within certain limits. The following is a summary of some of the more interesting results observed.

1. With a short length of condenser and a very free escape of steam, the condensation observed was equivalent to 22·2 thermal units F. per square foot per second, for a difference of temperature of 28°·5 F. between the steam and the metal surface. This is equivalent to a rate of condensation of 0·78 T.U.F. per degree-second, reckoned per square foot of the surface of the metal. This was the smallest value of the rate observed. The platinum tube was vertical, and the current of steam downwards, conditions which tended to keep the surface of the metal comparatively clear of condensed water.

2. With the same conditions, but with a length of tube nearly twice as great exposed to the steam, the condensation observed was 22·3 T.U.F. per square foot per second, for a difference of temperature of 25°·3 F.

This gives a rate of 0·88 per degree-second. The lower half of the tube was more thickly covered with water than the upper half, the steam also was full of flying spray, which may have assisted in conveying heat to the metal, and in maintaining the same rate of condensation on the lower half of the tube as on the upper half, in spite of the somewhat higher temperature of the circulating water in the lower half.

3. With the same arrangement, but with the steam current reversed and reduced until the escape was as gentle as possible consistently with keeping the tube full of steam and entirely excluding air, a somewhat larger rate of condensation was observed, namely, 23·6 T.U.F. per square foot per second. The pressure throughout the tube was very nearly atmospheric, and the gentle upward current of steam tended to keep the tube very thickly covered with drops and rivulets of water. The difference of temperature was only 22°·0 F., giving a rate of condensation of 1·07 T.U.F. per degree-second. This is equivalent to 2·25 watts (joules per second) per square cm. per 1° C., and was the largest value observed throughout the work. It would appear probable that the surface exposed by the drops is so much greater (in the present instance about twice as great) than the surface of the metal, and that the drops themselves are in such rapid motion, that the increase of surface by facilitating condensation more than compensates for any resistance which the water-film may offer to the passage of heat to the metal.

4. To verify this view, the outer glass tube was replaced by a much smaller tube, so as to leave very little space for the steam current. The pressure of the steam was thus raised to nearly four inches of mercury above the atmospheric at the entrance of the tube, and the surface of the platinum was violently scoured by a spiral rush of steam and spray. Under these conditions, the condensation observed was reduced to 19·2 T.U.F. per square foot per second, instead of being increased as might naturally have been expected with so strong a current of steam. The effect of the energetic scouring of the metal surface was shown by a slight rise of temperature of the metal as compared with the previous experiments. The observed difference of temperature between the metal and the steam in this case was 19°·8 F., giving a rate of condensation of 0·97 T.U.F. per degree-second.

From these and similar observations, in which the conditions of the experiments were varied to a certain extent in points of detail, it may be concluded that the presence of water on a metal surface may tend to increase rather than diminish the amount of condensation. The rate of condensation of steam at 212° F., allowing for the fact that in these experiments the surface was unduly increased by the presence and motion of the water drops, would appear to be at least of the same order of magnitude as the value deduced from experiments on the cyclical condensation in the cylinder of a working steam-engine in which the temperature of condensation varied from 290 F. to 330° F., and the rate deduced was 0·74 T.U.F. per square foot per degree-second. Since, however, it is possible that the latter value was diminished to an uncertain extent by a slight film of grease on the hot and dry surface, and since the value deduced from the surface-condenser method is perhaps a little too large owing to the presence of the water-film, it would be unsafe to conclude that the rate of condensation is the same at different temperatures, although the evidence so far as it goes appears at present to point in that direction.

Comparing the three different methods of experiment, which all lead to a similar result, it may be regarded as highly probable that the old view of an infinite rate of condensation requires revision, and that the value of the rate of condensation of steam on a metal surface, as determined by the author's previous experiments, is at least a first approximation to the truth. The question at issue is one of fundamental importance in the theory of the steam-engine, and the authors have shown in the Paper already quoted that, if the law of condensation there proposed be admitted, a number of interesting practical deductions can be made, and problems may be solved which have not hitherto been regarded as amenable to other than empirical treatment.

Calibration of Instruments used in Engineering Laboratories.—Appendix to Report of the Committee, consisting of Professor A. B. W. KENNEDY, *F.R.S.* (*Chairman*), Professor J. A. EWING, *F.R.S.*, Professor D. S. CAPPER, Professor T. H. BEARE, *and* Professor W. C. UNWIN, *F.R.S.* (*Secretary*).

THE Committee obtained measurements of the elongations under tension of a set of test bars made by different instruments and observers. A comparison of the results was given in the Report for 1896, pp. 538–548.

The Committee applied to Professor A. Martens, of the Technische Hochschule, Charlottenburg, to make some similar measurements with the instruments at Berlin, for comparison with the measurements made in this country. Professor Martens very kindly consented to make these measurements, but his report was not received till February this year.

The measurements at Berlin appear to have been made with the greatest care, and with three different testing machines. The variation in the extensions with different loads is less than that in most of the measurements made in this country.

The following is a general comparison of the average result obtained at Berlin, with the average of all the results by different observers in this country for corresponding bars :—

Coefficient of Elasticity. (Tons per square inch.)

Bars	Average of Berlin results	Average of results in this country
E, F, $1\frac{1}{4}$ inch diameter	13264	13249
K, L, $\frac{3}{4}$ inch diameter	13373	13245
A, B, 2 inches by $\frac{1}{2}$ inch	13041	13193

The tables of details are appended :—

Results of Tensile Tests made with Rod E.

Diameter	$d = 31{\cdot}8$ millimetres.
Section	$F = 794{\cdot}2$ square millimetres.
Measured Length	$L = 200$ millimetres.
Elongation-measurer	Martens' Mirror Apparatus.
Machine	Werder's System.
Temperature of room	$t = 16°$ to $17°$ Centigrade.

Load P. Kilos	Increment of Elongation in 0·0001 mm. for every 2,540 kilos.									Remarks
	In series of experiments								Average	
	1	2	3	4	5	6	7,	8		
2,540	(306·2)	(305·5)	(306·7)	—	—	—	—	—	(306·5)	The experiments on the 'Werder' machine were commenced with an initial load of 2,540 kilos. The elongations in brackets () per 2,540 kilos were determined on the 50 tons Pohlmeyer machine.
5,080	301	309	308	307	308	306	309	309	307·1	
7,620	308	308	306	306	304	307	309	306	306·8	
10,160	310	306	307	307	305	305	307	308	306·9	
12,700	308	303	305	303	303	303	306	304	304·4	
15,240	307	305	303	305	304	306	306	306	305·3	
17,780	309	309	307	309	306	304	307	307	307·3	
20,320	306	308	305	304	307	307	306	305	306·0	
Average.	307·0	306·9	305·9	305·9	305·3	305·4	307·1	306·4	306·2	
2,540	−4	+9	+2	±0	+1	+4	+1	+4	—	Residual readings on taking off the load.

$$\text{Modulus of elasticity } E = \frac{2540 \,.\, 200 \,.\, 10000}{794{\cdot}2 \,.\, 306{\cdot}2} = 20{,}890 \text{ kilos per sq. millimetre.}$$
$$= 13{,}249 \text{ tons per sq. inch.}$$

Results of Tensile Tests made with Rod K.

Diameter . . . . $d = 19{\cdot}0$ millimetres.
Area of Section . . . . $F = 283{\cdot}5$ square millimetres.
Measured Length (length between marks) . $L = 200$ millimetres.
Apparatus used for measuring elongation . Mirror Apparatus by Martens.
Temperature of room . . . . . . $t = 17°$ Centigrade.

Load P. Kilos.	Increment of Elongation in 0·0001 mm. per 1,270 kilos determined on :													Total Average.
	'Martens' Machine.					'Werder' Machine.				50-ton Pohlmeyer Machine.				
	In series of experiments.				Average.	In series of expmts.			Average.	In series of expmts.			Average.	
	1	2	3	4		1	2	3		1	2	3		
1,270	424	424	427	(431)	425·0	—	—	—	—	432	424	426	427·3	(426·3)
2,540	425	424	424	425	424·5	431	426	427	428·0	425	426	427	426·0	426·2
3,810	425	424	423	423	423·8	423	428	427	426·0	426	423	425	424·7	424·8
5,080	430	424	433	422	427·3	424	426	428	426·0	422	425	424	423·7	425·7
6,350	427	431	422	426	426·5	425	425	426	425·3	425	425	425	425·0	425·6
7,620	426	425	426	426	425·8	423	426	424	424·3	419	420	424	421·0	423·7
Average	426·2	425·3	425·8	424·4	425·5	425·2	426·2	426·4	425·9	424·8	423·8	425·2	424·6	425·4
0	+4	−1	+5	+2	—	—	—	—	—	+1	±0	±0	—	Residual Reading on taking off the load.
1,270	+5	+5	+2	(+2)	—	+1	±0	+1	—	−1	+2	+2	—	

$$\text{Modulus of elasticity } E = \frac{1270 \,.\, 200 \,.\, 10000}{283{\cdot}5 \,.\, 425{\cdot}4} = 21{,}061 \text{ kilos per sq. mm.}$$
$$= 13{,}373 \text{ tons per sq. in.}$$

Results of Tensile Tests made with Rod B.

Width	$b = 50{\cdot}4$ millimetres.
Thickness	$d = 12{\cdot}9$ millimetres.
Section	$F = 650{\cdot}2$ square millimetres.
Measured Length	$L = 100$ millimetres.
Elongation-measurer	Martens' Mirror Apparatus.
Machine	Werder's System.
Temperature of room	$t = 17°$ Centigrade.

Load P. Kilos	Increment of Elongation in 0·0001 mm. for every 2,540 kilos.						Remarks
	In series of experiments					Average	
	1	2	3	4	5		
5470	—	—	—	—	—	—	$E = \frac{2540 \cdot 100 \cdot 10000}{650{\cdot}2 \cdot 190{\cdot}2} = 20{,}539$ kilos per square mm. $= 13{,}041$ tons per square in.
5080	192	192	192	192	191	191·8	
7620	189	190	185	191	189	188·8	
10160	190	192	191	188	191	190·4	
12700	190	188	191	192	188	189·8	
Average	190·3	190·5	189·8	190·8	189·8	190·2	
2540	±0	+2	±0	+1	±0	Residual readings on taking off the load	

Screw Gauge.—Second Report of the Committee, consisting of Mr. W. H. PREECE (*Chairman*), Lord KELVIN, Sir F. J. BRAMWELL, Sir H. TRUEMAN WOOD, Major-Gen. WEBBER, Col. WATKIN, Messrs. CONRAD W. COOKE, R. E. CROMPTON, A. STROH, A. LE NEVE FOSTER, C. J. HEWITT, G. K. B. ELPHINSTONE, T. BUCKNEY, E. RIGG, *and* W. A. PRICE (*Secretary*), *appointed to consider means by which Practical Effect can be given to the Introduction of the Screw Gauge proposed by the Association in* 1884.

AT the meeting in Liverpool in 1896 your Committee reported that sufficiently accurate gauges of the British Association screw threads were not generally procurable. They described methods of exactly measuring male threads, and proposed a form of gauge for male threads which they anticipated could be more accurately produced, and more easily verified than the forms in common use.

In continuation of this course they have been in correspondence with some of the principal tool-makers in England and America, with a view to procuring accurate gauges of the different screw threads of the British Association system constructed on the lines indicated in their last report.

The Pratt and Whitney Company of Hartford, Connecticut, had already begun to construct tools for these threads, when the Secretary of the Committee wrote to them, and are giving close attention to their accurate production. The Company have kindly promised to communicate with the Committee as soon as the work is sufficiently advanced to allow

them to make proposals for the supply of the gauges, and the Committee hope that exact gauges will soon be obtainable from this source.

In the meantime they ask to be reappointed, with a grant of 20*l.*, including the 10*l.* granted last year but not drawn.

Linguistic and Anthropological Characteristics of the North Dravidian and Kolarian Races.—Interim Report of the Committee, consisting of Mr. E. SIDNEY HARTLAND (*Chairman*), Prof. A. C. HADDON, Mr. J. L. MYRES, *and* Mr. HUGH RAYNBIRD, Jun. (*Secretary*).

THE Committee invited Mr. William Crooke, late of the Indian Civil Service, the author of 'The Tribes and Castes of the North-West Provinces,' recently issued by the Indian Government, and other important works on the populations of India, to join them. Mr. Hugh Raynbird, jun., whose materials the Committee were appointed to examine, has, however, been prevented by various engagements during the current year from continuing and completing the laborious work of transcribing and translating his collections. The Committee are therefore unable to make any further report this year to the Association; and they deem it unnecessary to ask for reappointment at present. The grant has not been drawn from the Treasurer.

Mental and Physical Deviations from the Normal among Children in Public Elementary and other Schools.—Report of the Committee, consisting of Sir DOUGLAS GALTON (*Chairman*), Dr. FRANCIS WARNER (*Secretary*), Mr. E. W. BRABROOK, Dr. J. G. GARSON, *and* Mr. E. WHITE WALLIS. (*Report drawn up by the Secretary.*)

THE Committee reappointed to act in conjunction with the Committee appointed for the same purpose by the Congress of Hygiene and Demography continued to act with that body in the study of conditions of childhood. Last year we referred to a report[1] published on 100,000 children examined. Following the circulation of that report, it was decided to establish a society to continue inquiry and research. This has been effected under the title of 'The Childhood Society: for the Scientific Study of the Mental and Physical Conditions of Children,' of which the Earl of Egerton and Tatton is president, and Sir Douglas Galton chairman. This society now possesses all the records of inquiries conducted since 1888, and we have received from them full means of access to these valuable records and substantial assistance in preparing this report.

[1] Report on the Scientific Study of the Mental and Physical Conditions of Childhood, with particular reference to children of defective constitution, and with recommendations as to education and training, based on 100,000 children examined. Published at Parkes Museum, Margaret Street, London, W., the office of the Childhood Society.

In presenting our fifth annual report we now give an account of 1,120 children who appear to require special care and training as being sub-normal in their mental or physical status. The cases dealt with are derived from three sources:—(1) Records of children seen in public elementary schools, 1888–91; (2) children similarly examined, 1892–94; (3) cases collected by the Charity Organisation Society in various parts of London and presented for report as to mental and physical status. These were examined and individually reported on by Dr. Francis Warner. This portion of the work is new, and was specially selected, as evidence concerning these children was asked and obtained from these inquiries by departmental committees of the Local Government Board, the Home Office, and the present Committee of the Education Department on Defective Children. The evidence is published in their parliamentary reports, and some of the recommendations made have been adopted.

The class 'children who appear to require special care and training' includes all cases given as 'exceptional children' (see Group 5), and in addition 'all children mentally dull, with defects in development, abnormal nerve-signs, and low nutrition,' *i.e.*, Group 27.

EXCEPTIONAL CHILDREN.—This includes all children whose physical or mental conditions show them to be obviously at a permanent disadvantage therefrom in social life. This group includes: Idiots (76); imbeciles (77); 'children feebly gifted mentally' (78); children mentally exceptional (79); epileptics and children with history of fits during school life (80); dumb children (81); and all children crippled, deformed, maimed, paralysed. All these exceptional children need to be considered individually as to their special requirements.

Idiots includes all children who on account of their bodily and brain defects and the absence of mental power might be certified as idiots under the Idiots Act and sent to an asylum.

Imbeciles.—This includes all children who might be certified as mentally imbecile and transferred to an asylum. Speaking generally, these are less hopeless cases than the idiots, and more educable under industrial training. Some of these cases were the result of disease, not of congenital defect of brain.

'*Children feebly gifted mentally.*'—These children are distinctly deficient in mental power, but might not be certified as imbeciles, and are therefore not fit for such medical certification. No child was registered in this group unless it was believed upon evidence observed and the teacher's report combined to be incapable of school work in the ordinary classes. It is difficult to define what physical conditions seen, as apart from mental tests, indicate the child as unfitted in mental capacity for the usual methods of education, and an arbitrary attempt to do so has not been made. There appears, however, to be a large class of 'children feebly gifted mentally' with defect of mental power short of imbecility, but still with some deficiency.

Children mentally exceptional.—These children, while not necessarily mentally dull, and without brain power, appeared deficient in certain mental characteristics and in moral sense, such as habitual liars, thieves, and incendiaries; others were liable to attacks of total mental confusion, or periods of total mental ineptitude or violent passion, or were moral imbeciles. Some of these children were the offspring of insane parents or criminals. It is quite possible that some of these children were really

epileptic or subject to *petit-mal.* Some of these children while thus mentally exceptional were not ordinarily dull pupils in schools.

Epileptics and children with history of fits during school life.—In every school, inquiry was made for children subject to fits, whether occurring in school or alleged to occur at home during school life and given as a reason for absence from school. A report given as to history of fits was recorded, and the case was entered in this group, but at the inspection of a school facts could not be usually observed proving the child to be epileptic.

Children crippled, maimed, deformed, or paralysed.—Any child crippled, maimed, deformed, or paralysed was included in this group. Conditions of disease and paralysis were in various stages, but in all cases the child appeared to be at some permanent disadvantage. The conditions causing crippling were in various stages: many of these children were quite capable of work and play, some were mentally defective; they varied greatly in brain power and in physical health.

A card was specially prepared for each of these cases, showing the defects present. The tables were prepared by sorting and classifying such cards:—

School __________ *Card No.* __________

St^d __________ *Reg. No.* __________ **BOYS.**

Age __________ __________ *Spl. Rep^t* __________

A DEVELOPMENT DEFECTS.
a 1 CRANIUM.
2 Large.
3 Small.
4 Bossed.
5 Forehead.
6 Frontal ridge.

b 11 EXTERNAL EAR.
c 12 EPICANTHIS.
d 13 PALATE.
14 Narrow.
15 V-shaped.
16 Arched.
17 Cleft.
18 Other types.
e 19 NASAL BONES.
f 20 GROWTH SMALL.
g 21 OTHER DEVELMT. DFTS.

B NERVE-SIGNS.
43 General balance.
44 Expression.
45 Frontals overact.
46 Corrugation.
47 O. oculi lax.
48 Eye movements.
49 Head balance.
50 Hand weak.
51 Hand nervous.
52 Finger twitches.
53 Lordosis.
h 54 OTHER NERVE-SIGNS.

C NUTRITION.
D DULL.
E EYE-CASES.
64 Squint.
65 Glasses plus.
66 Glasses minus.
67 Myopia, no glasses.
68 Cornea disease.
69 Eye, lost accident.
70 Eye, lost disease.

F RICKETS.
G EXCEPTIONAL CHILDREN.
i 82 CRIPPLES.

A B C D E F G

It is obvious that different educational arrangements are needed for the children 'feebly gifted mentally,' according as they are or are not blind or dumb, while the epileptics form a particularly difficult class to deal with. Again; crippled children who are not mentally deficient or paralysed, are not to be grouped with those so defective.

Following the experience gained in giving evidence before the departmental committees and those responsible for the care of exceptional children, the cases have been grouped as given in Tables A. The total numbers feebly gifted mentally are easily obtainable by addition of the eleven sub-groups.

In the tables the boys and girls are arranged in age-groups, and as to the educational standards.

In Tables B the cases are arranged as in our report presented last year.

Standard O contains children too old for the infant school and too dull or backward for Standard I.

The primary main classes of defect are indicated in the tables by symbols :—

A. *Defect in development only;* not in combination with other class of defect.

B. *Abnormal nerve-signs only;* not in combination with other class of defect.

C. *Pale, thin, or delicate only.*

D. *Reported as mentally dull or backward only.*

Six other primary groups are arranged by taking cases with two main classes of defect only.

Four primary groups present three main classes of defect only.

One primary group presents the four main classes of defect combined in each case.

The remainder—groups E, F, and G—contain the cases with defects not classed above as main classes; such as eye cases, children maimed or crippled, &c.

To obtain the total number of cases with any class of defect, whether combined with other class of defect or not, the numbers representing all the primary groups containing such defect must be added together. The total or compound group AB=primary AB+ABC+ABD+ABCD.

The Committee desire to be reappointed, to act in conjunction with the Childhood Society, for the scientific study of the mental and physical conditions of children, and ask a grant of £20 in aid of this work.

TABLE A 1.—*Cases seen in Public Elementary Day Schools examined* 1888–91, *showing 'the children who appeared to require special care and training,' arranged in sub-classes, presenting the class or classes of defect named only. The total number of children seen is given in the last line. The cases are distributed first in age-groups, secondly under school standards.*

Group	—	7 years and under		8–10 years		11 and over		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total Number	
		B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
77 . . .	Imbecile and idiot only .	4	1	3	3	3	—	7	1	—	—	2	3	1	—	—	—	—	—	—	—	10	4
77 E . .	" with eye defect only	1	—	2	1	1	—	2	—	—	—	1	1	—	—	1	—	—	—	—	—	4	1
77 E (i 82) .	" with eye defect and crippled	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
77 E 81 . .	" with eye defect and dumb	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
77 80 . .	" and epileptic only	—	1	—	1	2	—	—	2	—	—	1	—	1	—	—	—	—	—	—	—	2	2
77 (i 82) . .	" and crippled only .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 . . .	Feebly gifted mentally only	10	13	16	10	15	4	12	9	1	—	16	11	7	5	3	1	2	1	—	—	41	27
78 E . .	" " with eye defect only	—	1	3	3	3	—	1	—	—	—	1	2	4	1	—	—	—	1	—	—	6	4
78 E (i 82) .	" " with eye defect and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 E 81 . .	" " with eye defect and dumb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 E 80 . .	" " with eye defect and epileptic	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 E 80 (i 82) .	" " with eye defect, epileptic, and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 80 . .	" " and epileptic only	1	—	3	2	1	—	4	—	—	—	—	1	—	1	1	—	—	—	—	—	5	2
78 80 (i 82) .	" " epileptic and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 (i 82) . .	" " and crippled only	2	1	—	1	—	—	2	1	—	—	—	1	—	—	—	—	—	—	—	—	2	2
78 81 . .	" " and dumb only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 100 . .	" " and blind or nearly so	—	—	—	—	—	2	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	2

TABLE A 1—*continued.*

Group	—	7 years and under		8–10 years		11 and over		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total Number	
		B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
79	Mentally exceptional only	2	—	—	1	—	3	2	—	—	—	—	—	—	1	—	3	—	—	—	—	2	4
79 E	" with eye defect only	—	—	1	—	—	2	—	—	—	—	1	—	—	—	—	—	—	2	—	—	1	2
79 80	" and epileptic only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79 81	" and dumb only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80	Epileptic only	4	3	8	4	7	7	4	3	—	—	4	1	1	5	2	3	8	2	—	—	19	14
80 E	" with eye defect only	1	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	2	—
80 E (*i* 82)	" with eye defect and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80 (*i* 82)	" and crippled only	1	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	2	—
80 81	" and dumb only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(*i* 82)	Crippled only	14	13	31	15	21	11	16	11	—	—	9	7	10	7	13	5	18	9	—	—	66	39
(*i* 82) E	" with eye defect only	—	1	—	1	—	1	—	1	—	—	—	1	—	—	—	1	—	—	—	—	—	3
81	Dumb only	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
100	Blind or nearly so	—	—	1	—	—	1	—	—	—	—	—	—	—	—	1	1	—	—	—	—	1	1
101	Chorea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
103	Heart disease	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	Total number of exceptional children as above	42	34	69	42	55	31	53	28	2	—	36	29	24	20	21	15	30	15	—	—	166	107
27	Dull pupils with some defect in development, also abnormal nerve-signs and pale, thin, or delicate; but not included above as exceptional children	38	56	49	48	30	26	25	32	6	1	24	39	20	23	17	19	25	16	—	—	117	130
12	Total number of children who appear to require special training (Group 12)	80	90	118	90	85	57	78	60	8	1	60	68	44	43	38	34	55	31	—	—	283	237
	Number of children seen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18,638	17,760

TABLE B 1.—*Cases seen in Public Elementary Day Schools examined* 1888–91, *showing 'the children who appear to require special care and training,' arranged in primary groups, presenting only the class of defect indicated by symbols in the margin and explained in the text. The total number of children seen in these schools is given in the last line. The cases are distributed first in age-groups, secondly under school standards.*

Primary	7 years and under		8–10 years		11 and over		Total Number		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total Number	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
Group G and A	1	2	3	2	4	—	8	4	1	2	—	—	1	1	1	—	1	—	4	1	—	—	8	4
" B	6	2	13	2	9	3	28	7	5	2	—	—	2	—	5	3	7	1	9	1	—	—	28	7
" C	—	—	2	1	1	—	3	1	1	—	—	—	1	1	—	—	1	—	—	—	—	—	3	1
" D	4	2	6	6	4	—	14	8	6	2	—	—	2	5	1	—	2	1	3	—	—	—	14	8
" A B	3	—	3	1	3	—	9	3	2	—	—	—	2	—	—	—	2	1	3	2	—	—	9	3
" A C	1	4	—	1	—	2	1	7	1	4	—	—	—	—	—	1	—	—	—	2	—	—	1	7
" A D	—	1	3	3	3	1	6	5	—	—	—	—	3	1	2	2	—	—	1	2	—	—	6	5
" B C	—	—	—	—	1	1	1	1	—	—	—	—	—	—	—	—	—	—	1	1	—	—	1	1
" B D	8	4	7	6	9	7	24	17	11	4	—	—	6	4	4	4	1	1	2	4	—	—	24	17
" C D	—	2	—	—	—	—	—	2	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	2
" A B C	2	—	2	—	1	—	5	—	2	—	—	—	1	—	—	—	—	—	2	—	—	—	5	—
" A B D	6	7	13	6	11	4	30	17	12	4	1	—	3	9	7	3	4	1	2	—	—	—	30	17
" A C D	1	1	1	3	2	2	4	6	1	1	—	—	2	1	—	2	—	2	1	—	—	—	4	6
" B C D	3	—	2	1	1	—	6	1	3	—	—	—	2	1	—	—	1	—	—	—	—	—	6	1
" A B C D	6	6	8	8	4	1	18	15	7	6	1	—	9	5	1	3	—	1	—	—	—	—	18	15
" E F —	1	3	6	2	2	8	9	13	1	2	—	—	2	1	3	1	2	7	2	2	—	—	9	13
Total Group G	42	34	69	42	55	31	166	107	53	28	2	—	36	29	24	20	21	15	30	15	—	—	166	107
A B C D not in Group G	38	56	49	48	30	26	117	130	25	32	6	1	24	39	20	23	17	19	25	16	—	—	117	130
Total Group 12	80	90	118	90	85	57	283	237	78	60	8	1	60	68	44	43	38	34	55	31	—	—	283	237
Number seen	—	—	—	—	—	—	18,638	17,740	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18,638	17,740

TABLE A 2.—*Cases seen in Public Elementary Day Schools, examined 1892–94, showing 'the children who appear to require special care and training,' arranged in sub-classes, presenting the class or classes of defect named only. The total number of children seen is given in the last line. The cases are distributed first in age-groups, secondly under school standards.*

Group	—	7 years and under		8-10 years		11 and over		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total Number	
		B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
77 76	Imbecile and idiot only	1	—	1	—	—	1	1	—	—	—	1	1	—	—	—	—	—	—	—	—	2	1
77 E	" with eye defect only	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
77 E (*i* 82)	" with eye defect and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77 E 81	" with eye defect and dumb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77 80	" and epileptic only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77 (*i* 82)	" and crippled only	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
78	Feebly gifted mentally only	16	16	12	13	9	11	16	11	—	6	17	17	3	3	—	2	1	1	—	—	37	40
78 E	" " with eye defect only	2	2	3	2	3	1	2	—	2	1	2	3	2	—	—	1	—	—	—	—	8	5
78 E (*i* 82)	" " with eye defect and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 E 81	" " with eye defect and dumb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 E 80	" " with eye defect and epileptic	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 E 80 (*i* 82)	" " with eye defect, epileptic and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 80	" " and epileptic only	—	—	2	3	1	2	2	—	—	3	—	1	—	1	1	—	—	—	—	—	3	5
78 80 (*i* 82)	" " epileptic and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78 (*i* 82)	" " and crippled only	—	1	—	1	1	—	—	1	—	—	—	—	—	1	—	—	1	—	—	—	1	2
78 81	" " and dumb only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

78 100	„ „ and blind or nearly so	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79	Mentally exceptional only	1	—	3	—	—	3	1	—	—	—	—	—	1	—	1	—	1	3	—	—	4	3
79 E	„ with eye defect only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79 80	„ and epileptic only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79 81	„ and dumb only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80	Epileptic only	9	9	3	12	5	7	8	8	1	1	1	3	—	7	2	2	5	7	—	—	17	28
80 E	„ with eye defect only	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	1	—	—	—	—	1	1
80 E (i 82)	„ with eye defect and crippled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80 (i 82)	„ and crippled only	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
80 81	„ and dumb only	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(i 82)	Crippled only	12	18	23	13	36	23	12	11	2	3	13	16	9	7	7	8	28	9	—	—	71	54
(i 82 E)	„ with eye defect only	2	—	1	—	1	2	1	—	—	—	1	1	—	—	1	—	1	1	—	—	4	2
81	Dumb only	1	1	1	—	2	—	1	1	—	—	2	—	—	—	1	—	—	—	—	—	4	1
100	Blind or nearly so	—	2	—	1	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	3
101	Chorea	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
103	Heart disease	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	Total number of exceptional children as above	45	50	50	45	58	53	46	35	5	14	37	43	15	21	13	14	37	21	—	—	153	148
27	Dull pupils with some defect in development, also abnormal nerve-signs, and pale, thin, or delicate; but not included above as exceptional children	29	39	34	23	10	8	21	19	5	5	27	34	5	5	8	3	7	4	—	—	73	70
12	Total number of children who appear to require special training (Group 12)	74	89	84	68	68	61	67	54	10	19	64	77	20	26	21	17	41	25	—	—	226	218
	Number of children seen	—	—	—	—	—	—	7055	6274	354	323	4231	4191	3710	3465	3541	3434	7396	6026	—	—	26287	23713

TABLE B 2.—*Cases seen in Public Elementary Day Schools, examined* 1892–94, *showing 'the children who appear to require special care and training,' arranged in primary groups, presenting only the class of defect indicated by symbols in the margin and explained in the text. The total number of children seen in these schools is given in the last line. The cases are distributed first in age-groups, secondly under school standards.*

Primary	7 years and under		8–10 years		11 and over		Total Number		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total Number	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
Group **G** and **A**	1	4	1	—	2	1	4	5	1	—	—	1	—	3	—	—	—	1	3	—	—	—	4	5
" **B**	3	4	5	7	6	9	14	20	3	4	—	1	2	1	3	6	—	4	6	4	—	—	14	20
" **C**	2	—	2	1	—	2	4	3	1	—	1	—	1	1	—	—	1	—	—	2	—	—	4	3
" **D**	7	4	4	7	11	7	22	18	6	3	1	1	3	5	3	6	1	4	8	5	—	—	22	18
" **AB**	1	2	1	—	4	2	6	4	1	—	1	—	—	2	—	2	2	—	2	—	—	—	6	4
" **AC**	1	—	1	—	1	—	3	—	1	—	—	—	—	—	1	—	—	—	1	—	—	—	3	—
" **AD**	5	2	1	2	5	1	11	5	4	1	—	2	4	2	—	—	—	—	3	—	—	—	11	5
" **BC**	—	—	—	1	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
" **BD**	8	11	13	11	5	13	26	35	9	8	—	4	12	10	2	6	2	3	1	4	—	—	26	35
" **CD**	—	—	—	1	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
" **ABC**	—	2	—	—	—	—	—	2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2
" **ABD**	6	6	10	7	7	6	23	19	9	5	2	3	6	7	4	2	2	1	—	1	—	—	23	19
" **ACD**	—	2	—	1	1	1	1	4	—	—	—	—	—	4	—	—	1	—	—	—	—	—	1	4
" **BCD**	1	1	1	3	—	1	2	5	1	—	—	1	1	3	—	1	—	—	—	—	—	—	2	5
" **ABCD**	4	6	1	2	2	1	7	9	4	5	—	—	2	4	1	—	—	—	—	—	—	—	7	9
" **EF**	6	6	10	3	14	8	30	17	6	7	—	—	6	—	1	4	4	1	13	5	—	—	30	17
Total Group **G**	45	50	50	46	58	52	153	148	46	35	5	14	37	43	15	21	13	14	37	21	—	—	153	148
ABCD not in Group **G**	29	39	34	23	10	8	73	70	21	19	5	5	27	34	5	5	8	3	7	4	—	—	73	70
Total Group 12	74	89	84	69	68	60	226	218	67	54	10	19	64	77	20	26	21	17	44	25	—	—	226	218
Number seen	—	—	—	—	—	—	—	—	7055	6274	354	323	4231	4191	3710	3465	3541	3434	7396	6026	—	—	26287	23713

TABLE A 3.—*Cases as collected by the Charity Organisation Society in London, and reported on individually, showing 'the children who appeared to require special care and training,' arranged in sub-classes, presenting the class or classes of defect named only. The total number of children seen is given in the last line. The cases are distributed first in age-groups, secondly under school standards.*

Group	—	7 years and under		8–10 years		11 and over		Infants		Standard 0 Special		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total	
		B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
77	Imbecile and idiot only	—	—	2	1	5	3	—	—	—	—	1	—	—	—	—	—	1	—	5	4	7	4
77 E.	,, with eye defect only	—	—	—	1	1	1	—	—	—	—	—	—	—	1	—	—	—	—	1	1	1	2
77 E (i 82)	,, with eye defect and crippled	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1
77 E 81	,, with eye defect and dumb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77 80	,, and epileptic only	1	—	1	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2	3	2	3
77 (i 82)	,, and crippled only	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	1	2	1	2
78	Feebly gifted mentally only	6	2	6	6	15	16	1	2	2	1	7	7	2	3	1	1	1	—	13	10	27	24
78 E.	,, ,, with eye defect only	—	—	2	3	6	3	—	—	2	2	1	1	1	—	1	—	—	—	3	3	8	6
78 E (i 82)	,, ,, with eye defect and crippled	—	1	2	2	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	3	2	3
78 E 81	,, ,, with eye defect and dumb	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
78 E 80	,, ,, with eye defect and epileptic	—	—	1	1	1	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1	2	1
78 E 80 (i 83)	,, ,, with eye defect, epileptic, and crippled	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—
78 80	,, ,, and epileptic only	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	2	1
78 80 (i 82)	,, ,, epileptic and crippled	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
78 (i 82)	,, ,, and crippled only	—	—	—	1	2	1	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2	2
78 81	,, ,, and dumb only	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
78 100	,, ,, and blind, or nearly so	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—

TABLE A 3—*continued.*

Group	—	7 years and under		8-10 years		11 and over		Infants		Standard 0 Special		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total	
		B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
79 . . .	Mentally exceptional only .	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	3	—
79 E . .	" with eye defect only	—	—	—	1	1	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	1	1
79 80 . .	" and epileptic only	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
79 81 . .	" and dumb only .	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—
80 . . .	Epileptic only	—	—	—	—	2	3	—	—	—	—	—	1	—	—	1	1	—	—	1	1	2	3
80 E. . .	" with eye defect only	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—
80 E (*i* 82) .	" with eye defect and crippled	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1
80 (*i* 82) . .	" and crippled only	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—
80 81 . .	" and dumb only .	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
(*i* 82) . .	Crippled only	3	—	1	—	2	2	—	—	—	—	1	—	—	1	—	—	—	—	5	1	6	2
(*i* 82) E . .	" with eye defect only	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	1
81 . . .	Dumb only	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	3	—
100 . . .	Blind or nearly so . .	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
101 . . .	Chorea	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	1	2	1	2
103 . . .	Heart disease . . .	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
5 . . .	Total number of exceptional children as above	17	6	24	20	38	39	2	2	5	3	11	10	5	5	3	2	3	1	50	42	79	65
27 . . .	Dull pupils with some defect in development, also abnormal nerve-signs, and pale, thin, or delicate; but not included above as exceptional children	4	1	2	2	3	—	—	—	2	1	2	—	—	—	—	—	—	—	5	2	9	3
12 . . .	Total number of children who appear to require special training (Group 12)	21	7	26	22	41	39	2	2	7	4	13	10	5	5	3	2	31	1	55	44	88	68
	Number of children seen .	31	11	45	24	66	54	2	2	10	4	26	13	18	8	7	6	6	4	73	52	142	89

TABLE B 3.—*Cases as collected by the Charity Organisation Society of London, and reported on individually, showing 'the children who appear to require special care and training,' arranged in primary groups, presenting only the class of defect indicated by symbols in the margin and explained in the text. The total number of children seen is given in the last line. The cases are distributed first in age-groups, secondly under school standards.*

Primary	7 years and under		8–10 years		11 and over		Total Number		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Over Standard III.		No Standard		Total Number	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
Group G and A . .	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—
„ B . .	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—
„ C . .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ D . .	3	—	—	—	—	1	3	1	—	—	—	—	—	1	—	—	—	—	—	—	3	—	3	1
„ A B. .	1	—	1	1	—	1	2	2	—	—	—	—	—	1	—	—	—	—	—	—	2	1	2	2
„ A C. .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ A D. .	—	—	1	—	2	3	3	3	—	—	1	—	2	2	—	—	—	1	—	—	—	—	3	3
„ B C. .	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
„ B D. .	7	—	3	3	6	12	16	15	—	—	—	—	4	1	—	2	1	1	1	—	10	11	16	15
„ C D. .	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
„ A B C .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ A B D .	2	—	8	7	22	9	32	16	1	—	2	1	5	4	5	1	1	—	—	—	18	10	32	16
„ A C D .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ B C D .	2	1	3	—	—	1	5	2	1	—	1	—	—	—	—	—	—	—	—	—	3	2	5	2
„ A B C D.	2	5	7	9	6	9	15	23	—	2	1	2	—	1	—	2	1	—	1	—	12	16	15	23
„ E F. .	—	—	—	—	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	1
Total Group G . .	17	6	24	20	38	39	79	65	2	2	5	3	11	10	5	5	3	2	3	1	50	42	79	65
A B C D not in Group G	4	1	2	2	3	—	9	3	—	—	2	1	2	—	—	—	—	—	—	—	5	2	9	3
Total Group 12 . .	21	7	26	22	41	39	88	68	2	2	7	4	13	10	5	5	3	2	3	1	55	44	88	68
Number seen . .	31	11	45	24	66	54	142	89	2	2	10	4	26	13	18	8	7	6	6	4	73	52	142	89

An Ethnological Survey of Canada.—First Report of the Committee, consisting of Dr. George Dawson (*Chairman and Secretary*), Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Dr. J. G. Bourinot, Abbé Cuoq, Mr. B. Sulte, Abbé Tanguay, Mr. C. Hill-Tout, Mr. David Boyle, Rev. Dr. Scadding, Rev. Dr. J. Maclean, Dr. Nerée Beauchemin, Rev. Dr. G. Patterson, Professor D. P. Penhallow, *and* Mr. C. N. Bell.

This Committee was nominated at the Liverpool meeting last year, with the object of initiating an ethnological survey of Canada on lines corresponding with those already followed by the Committee for the Ethnographical Survey of the United Kingdom, as well as to continue, so far as may be possible, work of the kind carried on since the Montreal meeting (1884) by the Committee on the North-Western Tribes of Canada. It comprises three members of the Committee for the Ethnographical Survey of the United Kingdom, including the Chairman and Secretary of that committee. Fourteen members resident in Canada were also nominated, but one of these, Mr. Horatio Hale, has since died.

In nominating the Canadian members some regard was given to geographical position, so that the principal regions of the Dominion would be represented. This, while necessary under the circumstances, has to some extent prevented an interchange of ideas as complete as might be desired. Some correspondence and discussion on the general scope of the work and the plans to be followed have, however, taken place. Messrs. E. W. Brabrook and E. S. Hartland have contributed valuable information and suggestions respecting the work of the similar committee for the United Kingdom, and several Canadian members have evinced a strong interest in the survey now to be undertaken.

It has not yet, however, been found practicable actually to initiate any systematic observations, to print and distribute the necessary schedules, or to provide sets of instruments for physical measurements, no funds being available for these purposes. It is believed that a number of observers may be enlisted in several of the numerous lines of inquiry which appear to be open to the Committee, embracing both the immigrant European population of Canada and its aborigines.

Of suggestions received from members of the Committee the following general considerations presented by Professor D. P. Penhallow, of McGill University, may be quoted :—

'The very unstable character of our population and the extensive mixture of races to be met with in a given community require that we should adopt somewhat different lines of procedure from those employed by the Committee for the United Kingdom. Therefore, while we might wisely adopt the main lines of investigation employed by the Committee for Great Britain, as embodied in their report for 1893 ("B.A. Report," 1893, p. 621), and while these lines of investigation might be applied to

both Indians and Europeans, they should be conducted with reference to—

'(*a*) Indian communities.

'(1) Displacement of tribes from their original locations through the intervention of Europeans.

'(2) The absorption of tribal remnants into existing tribes.

'(3) The infusion of French or other European blood.

'(*b*) European communities or families.

'(1) The precise European locality whence they originated.

'(2) The American locality of most continuous residence and of first settlement.

'(3) The environment at date of investigation.

'For the treatment of folklore as ethnological data, I do not think we can do better than adopt methods suggested by Mr. Gomme in his very valuable paper as embodied in the Report on Ethnographical Survey, Great Britain ("B.A. Report," 1896, Section H, p. 626, &c.).

'The great extent of country to be dealt with and the great length of time required to reach anything of the nature of complete results would seem to make it desirable that we proceed in the most systematic manner. The results might therefore be collated by—

'(1) Families or tribes.

'(2) Parishes.

'(3) Towns or villages.

'(4) Provinces and, as far as possible, a given locality should be studied exhaustively before another is undertaken.'

After some consultation with the members of the Committee who could most easily be communicated with, the following letter was addressed to the Committee generally :—

'Sir,—You have doubtless received some time ago from Mr. G. Griffith, Assistant General Secretary of the British Association for the Advancement of Science, a notification of your nomination as a member of the committee to organise an ethnological survey of Canada. It is hoped that you will be willing to take an active part in this important work, and, although it may not be possible to do much more than establish some plan of operations before the date of the forthcoming meeting of the Association in Toronto in August next, that you will now assist and advise in the perfecting of such plan.

'The project is based upon that being carried out by another committee of the Association nominated some years ago to "organise an ethnographical survey of the United Kingdom." This committee has already made several valuable and interesting reports, and has enlisted various local scientific societies and a number of individuals in the work.

'The chief objects of investigation in the United Kingdom are set out as follows :—

'(1) Physical type of the inhabitants.

'(2) Current traditions and beliefs ;

'(3) Peculiarities of dialect ;

'(4) Monuments and other remains of ancient culture ; and

'(5) Historical evidences as to continuity of race.

'It has been sought to discover, in the first place, the most suitable

localities for investigations; *i.e.*, those which are in large measure secluded from the change and mingling of population incident to large cities, and to select those villages and places where the people have remained for some generations, at least, comparatively undisturbed and homogeneous in character. In this way it is believed that the ethnographic elements going to make up the population of the United Kingdom may be traced, and the changes induced by the mingling of the various elements under different local conditions may be advantageously studied.

'As applied to Canada, it is obvious that an inquiry of the kind cannot be conducted on exactly the same lines. It resolves itself, in the first instance, into two distinct branches :—

'(1) That dealing with the white races, and

'(2) That dealing with the aborigines or Indians. Both are important and likely to yield results of great interest; but, while the second has already been recognised and pursued to some considerable extent, the first has remained almost untouched.

'In regard to the first, it is obvious that it includes two specially fruitful fields, one relating to the older centres of French colonisation in Quebec and Acadia, and the other to the half-breed population of Manitoba and the North-West, where French and Scottish immigrants have mingled with the native races.

'In Quebec and in the Acadian Provinces the researches of Abbé Tanguay have already placed on record the origin and descent of most of the old French families, and the basis thus established is an excellent one on which to build up a knowledge of any changes, whether physical or in language, customs and beliefs, due to the new environment in which the original French colonists have lived and increased. With that object it is desired to make, in the first place, a list of those localities in which development of the kind has been most uninterrupted and continuous, and in these to obtain the co-operation of some local observers who may be willing to devote time to special inquiries along fixed lines, of which the details may be subsequently elaborated.

'There are also, it is believed, many places in the older provinces of Canada in which English, Scottish, Irish, and other settlers have been so long established as to give rise to special peculiarities worthy of note.

'Respecting the aborigines or Indians of the eastern part of Canada, it may be stated that their language is now fairly well understood, while their customs, folklore and traditions, where these have not already been recorded, have largely passed away. But much remains as a profitable subject of investigation, particularly in respect to the location of ancient settlements and places of resort, burial places, routes of travel, &c. There are also many events connected with their early intercourse with the whites of which traditional accounts might yet be gathered with advantage.

'In the western part of Canada the investigation of all matters relating to the Indian tribes constitutes the most important branch of the work proposed; and although in most places great changes have occurred in recent years a vast amount of valuable material yet remains to be recorded, connected not only with their language, but also with their traditions, art, customs, mode of life, and physical characteristics. The time is rapidly passing away in which investigations of the kind may be made to advantage, and no effort should therefore be spared to collect

everything connected with these people. It may confidently be stated that no actually observed fact respecting them is without some definite value.

'With slight verbal changes the same main heads of investigation as have been already cited appear to be applicable to the native races; but, in addition, many other special lines of inquiry might be followed, such as the displacement of native tribes by the whites, the coalescence of diminished tribal communities in later years, and the absorption of the weaker of these by the stronger. Photographic records of all kinds will in connection with the native races possess great importance.

'The above suggestions of a general and preliminary kind are offered to the members of the Committee with the object of eliciting an expression of opinion, and further and more detailed plans such as may appear to be best for the objects in view. As no money grant is at the disposal of the Committee, the work must in the meantime, at least, be carried on entirely by the efforts of volunteers; but some means may, it is hoped, be found of obtaining a small fund applicable to the purposes of the Committee.

'In the meantime it is hoped that every member of the Committee will assist with advice in regard to the best organisation, not only for the collection, but also in respect to the collation and eventual publication of the facts.

'Yours faithfully,
(Signed) 'George M. Dawson.'

The Committee have been so fortunate as to obtain from Dr. Franz Boas and Mr. B. Sulte respectively the subjoined valuable contributions in the line of its investigations. 'The Growth of Toronto Children,' by Franz Boas; 'Origin of the French Canadians,' by B. Sulte. The first constitutes an interesting example of the importance attaching to accurate physical measurements. The second explains the nature of the foundations upon which further study of the French element of the Canadian population must rest.

APPENDIX I.

The Growth of Toronto Children. By Franz Boas.

In 1891, when active preparations for the World's Columbian Exposition were being made, Professor F. W. Putnam, director of the Peabody Museum of American Archæology and Ethnography, and then chief of the Department of Anthropology of the Exposition, placed me in charge of the Section of Physical Anthropology. At an early time during the preparation of the exhibits we agreed upon a plan to represent as fully as possible the growth and the development of American children. Valuable material was available, but it seemed desirable to extend the investigations over regions in which heretofore no observations had been collected. I submitted our plans to Mr. James Hughes, superintendent of public schools in Toronto, Ont., and to Professor Earl Barnes, of Leland Stanford, Jr., University. Through the interest taken by these gentlemen I have been enabled to obtain series of measurements of the school children of Toronto and of Oakland, Cal. The former series was taken under the supervision of Dr. Alexander F. Chamberlain; the

latter, under the direction of Professor Earl Barnes. In both of these series the same plan, excepting details, was followed.

The measurements embrace the following data: Stature without shoes, finger-reach, height sitting, weight. A series of special measurements of the head were taken, which, however, include only a few hundred individuals. The following statistical data were collected: Age, in years and months; place of birth; nationality of grandparents; place of birth of parents; occupation of parents; number and ages of brothers and sisters; order of birth of the child measured; and the mental ability as judged by the teacher.

In treating this material I have endeavoured to exclude a certain series of errors. The number of children of various ages which have been measured is not equal. The series begins with comparatively few children. The number increases from year to year, until, beginning with the ninth year, it decreases again. It follows from this fact that among the six-year-old children, for instance, there are more of the age six years and eleven months than of six years and no months; and that, on the other hand, among the fifteen-year-old children there are more of the age fifteen years and no months than of fifteen years and eleven months. In treating the various series of observations all children between six and seven, seven and eight, &c., have been grouped together, and usually the series is assumed to represent sizes for the average ages; that is, for six and a half, seven and a half, &c. On account of the varying frequency for the several months, this is not quite correct. Among the younger children the average will be a little more than six and a half, seven and a half, &c., while among those near the upper limit I judge it will be a little less than fourteen and a half, fifteen and a half, &c. By tabulating the various frequencies of various months for the children of Toronto the following results were obtained:—

Average Ages.

	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.	YRS. M.
Boys . .	5 6·7	6 6·2	7 5·6	8 5·7	9 5·7	10 5·8	11 5·5	12 5·8	13 5·7	14 5·1	15 4·9
Girls . .	6 6·1	7 6·1	8 5·7	9 5·1	10 5·8	11 5·7	12 5·5	13 5·5	13 5·3	15 5·2	16 4·3

The error resulting from this series may be very easily corrected by adding to the average a correction proportional to the deviation of period.

While the average may be corrected in this manner without much difficulty, the variability of the series for the whole year is affected in a much more complex manner. (I call the variability the square root of the mean of the squares of the individual deviations.) We will suppose that the variability did not change much in the course of one year, which, at certain periods of life is, however, not the case. Since the values of the average increase from month to month, it is clear that the range of variation for the early periods must begin at a lower point than for the later periods, so that the variation for the total year covers a wider series than the variations at a given moment do. It is possible to make the necessary reduction by a consideration of the number of individuals measured for all the different periods, and of the varying amount of variation. The amount of reduction due to this cause is shown in the following table, which refers to the measurements of American children, the series including measurements taken in Boston, Milwaukee, Toronto, Worcester (Mass.), St. Louis (Mo.), and Oakland (Cal.).

Variability of American Boys.

Age	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	16·5	17·5	18·5
Variability	±4·80	±4·92	±5·22	±5·53	±5·66	±5·90	±6·32	±6·80	±7·71	±8·66	±8·87	±7·75	±7·23	±6·74
Corrected variability	±4·40	±4·62	±4·93	±5·34	±5·49	±5·75	±6·19	±6·66	±7·54	±8·49	±8·78	±7·73	±7·22	—

I have preferred to calculate in the Toronto series the reduced amounts of variabilities in a different manner. I have grouped the observations according to quarterly periods, and calculated the variabilities for each of these periods. A comparison of the variabilities of these periods and of the full year periods are shown in the following tables :—

Boys.

Variability for	Ages											
—	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	
1. The whole year	±5·12	±4·82	±5·08	±5·58	±5·59	±6·15	±6·15	±6·80	±7·79	±8·55	±9·00	
2. Quarterly periods	±4·70	±4·65	±4·77	±5·38	±5·35	±6·02	±6·08	±6·61	±7·63	±8·22	±8·91*	

* Six-monthly periods.

Girls.

Variability for	Ages											
—	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	16·5
1. The whole year	±4·80	±4·80	±5·30	±5·53	±5·32	±6·20	±6·52	±6·96	±7·17	±6·35	±5·86	±5·35
2. Quarterly periods	±4·62	±4·73	±5·21	±5·34	±5·18	±5·89	±6·38	±6·90	±6·85	±6·13	±5·73	±5·63

In the following tables I give the averages of our series, with the corrections due to the considerations outlined in the preceding remarks. In interpreting these averages it must be understood that the *average* sizes do not represent the *typical* values of the measurement, because during childhood the distribution of the measurements is asymmetrical. Owing to the fact that children do not all grow at the same rate, but that some are retarded in development, while others are advanced beyond their age, the rate of growth differs in such a manner that the general distribution of the measurements does not follow the law of probabilities. I will explain this by considering the growth of sixteen-year-old girls. A great many of these girls will have reached the adult stage, and will have ceased growing, while others are not developed according to their age, and continue to grow. If we consider for a moment only those girls who as adults will have a certain stature, we recognise that many will have this stature, while others will still be shorter ; that is to say, the distribution of their statures will be asymmetrical. The same is true of all the other statures, and it will be seen for this reason that the whole distribution will be asymmetrical. On account of this peculiarity of the distribution of statures during the years of growth, the average values of the measurements must not be considered as the types of development for the various ages,

but as the nearest indices which can be obtained of the typical values. The following table shows the statures of Toronto children as compared to those of American children :—

Statures of Boys.

Ages	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	16·5
Toronto	106·2	111·1	116·8	121·8	126·7	131·5	135·9	140·1	145·4	151·5	157·6	
American	105·9	111·6	116·8	122·0	126·9	131·8	136·2	140·7	146·0	152·4	159·7	

Statures of Girls.

Ages	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	16·5
Toronto	105·2	110·4	116·0	120·7	125·3	130·9	136·1	141·9	148·0	153·3	156·0	156·7
American	104·9	110·1	116·1	121·2	126·1	131·3	136·6	142·5	148·7	153·5	156·5	158·0

Variability of Boys' Statures.

Ages	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	16·5
Toronto	±5·12	±4·82	±5·08	±5·58	±5·59	±6·15	±6·15	±6·80	±7·79	±8·55	±9·00	—
American	±4·80	±4·92	±5·22	±5·53	±5·66	±5·90	±6·32	±6·80	±7·71	±8·66	±8·87	±7·75

Variability of Girls' Statures.

Ages	5·5	6·5	7·5	8·5	9·5	10·5	11·5	12·5	13·5	14·5	15·5	16·5
Toronto	±4·80	±4·80	±5·30	±5·53	±5·32	±6·20	±6·52	±6·96	±7·17	±6·35	±5·86	±5·35
American	±4·64	±5·07	±5·25	±5·58	±5·73	±6·18	±6·83	±7·57	±7·37	±6·69	±5·96	±5·79

I have classed the material collected in the Toronto schools according to the order of birth of the children, in order to investigate if there is any difference between the first-born children and later-born children. An investigation of this subject, based upon material collected in Oakland, Cal., showed that a difference of this character exists, the first-born children, beginning with the sixth year, being taller and heavier than later-born children. The following table contains the results of this investigation, based on the Toronto material :—

Differences between Average Statures of Boys and Statures of Children of Various Orders of Birth, and their Mean Errors (mm.).

Age Years	First-born	Second-born	Third-born	Fourth-born	Fifth-born	Sixth-born	Seventh-born	Eighth-born	Ninth-born
5·5	+6±7·2	±0±6·1	−3±6·6	+6±7·8	−2±9·0	−16±11·8	−14±12·7	−13±14·0	—
6·5	+7±4·7	−3±4·4	−4±5·0	+2±5·6	+1±6·2	−4±8·3	−13±8·9	−16±10·2	−4±11·5
7·5	+3±4·0	+2±4·4	±0±5·0	±0±5·5	−5±6·6	+2±6·9	+1±8·5	−6±9·8	−13±12·4
8·5	+2±4·2	+4±4·5	−2±4·8	±0±5·6	−10±6·6	±0±7·2	−8±7·2	−6±9·6	−19±12·3
9·5	+4±4·1	−7±4·6	±0±5·1	±0±5·6	−13±6·3	−11±6·9	−10±8·3	+3±9·5	−13±11·3
10·5	−3±4·7	+5±5·5	−1±5·6	−6±6·2	−8±7·1	+6±7·4	−5±9·5	−15±10·8	+6±14·3
11·5	−1±5·0	+3±5·4	−2±5·9	−8±6·3	−2±6·9	−8±7·6	+6±10·1	−5±11·8	−15±15·5
12·5	−2±5·7	+1±6·3	+2±6·5	−6±7·9	+3±10·1	−4±8·1	−11±9·6	−16±12·2	−2±15·8
13·5	+7±6·3	+11±7·8	−13±9·1	−1±9·3	+2±12·1	−14±11·6	−31±15·9	+18±16·6	+9±22·6
14·5	+5±10·2	+1±10·8	+5±11·1	+2±13·6	−14±12·7	−12±16·8	−15±20·6	−5±24·1	—
15·5	−1±14·2	−1±20·0	−32±20·6	−8±18·4	+2±21·3	—	—	—	—
—	+2·3±1·6	+0·8±1·7	—	—	—	—	—	—	—

It appears, therefore, that the result is not quite certain, since the error is great as compared to the average difference. Since for later-born children the errors of the average are very great, I have not carried out the calculation. I have calculated the same differences, and their mean errors, for the statures of girls :—

Differences between the Average Statures of Girls and the Statures of First-born Girls, and their Mean Errors.

Ages		Ages	
6·5	+ 3 ± 4·7	13·5	+ 9 ± 6·7
7·5	+ 3 ± 4·5	14·5	+ 4 ± 7·2
8·5	+14 ± 4·6	15·5	− 8 ± 8·3
9·5	+ 7 ± 4·6	16·5	+ 4 ± 10·3
10·5	+ 1 ± 5·1		
11·5	+ 6 ± 5·1	Average	+5·3 ± 1·9
12·5	+ 6 ± 6·1		

This result is much more certain than that obtained by means of the measurements of boys. When we combine both we find that the difference of stature between the average of all the children and the average of the first-born children is in favour of the latter. The amount is 3·6 mm., with a mean error of 1·2 mm. It is therefore certain that first-born children are somewhat taller than later-born children, but the amount of the difference is not definitely known.

It is of interest to investigate the constitution of families. I have done so by recording for each year the number of children according to the order of their birth.

Total Number of Children examined according to the Order of Birth.

Order	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	Total
	3,392	2,880	2,385	1,858	1,368	1,021	790	511	360	226	116	60	29	14	5	1	2	—	1	15,019
Per cent.	22·6	19·2	15·9	12·4	9·1	6·8	5·3	3·4	2·4	1·5	0·8	0·4	0·2	0·1	—	—	—	—	—	
Mean error	±0·3	±0·3	±0·3	±0·3	±0·2	±0·2	±0·2	±0·1	±0·1	±0·1	±0·1	—	—	—						

From these data we can obtain an insight into the constitution of families in Toronto. The difference between the number of first- and second-born children shows the numbers of mothers having one child only ; the difference between the second- and third-born children gives the number of mothers who have two children, &c. In this manner the following table has been obtained :—

Number of Children		Number of Children	
1	15·1 ± 0·6	9	3·9 ± 0·3
2	14·6 ± 0·6	10	3·2 ± 0·3
3	15·5 ± 0·6	11	1·7 ± 0·2
4	14·5 ± 0·6	12	0·9 ± 0·2
5	10·2 ± 0·5	13	0·4 ± 0·1
6	6·8 ± 0·5	14	0·3
7	8·2 ± 0·5	15	0·1
8	4·5 ± 0·4	16	0·1

It is of interest to compare the number of children according to the order of their birth in various cities. I have tabulated for this purpose

the number of children in Oakland, Cal., according to the order of their birth, and found the following result :—

——	Toronto	Oakland, Cal.
	per cent.	per cent.
Number of first-born children	22·6	26·4
„ second-born children	19·2	22·3
„ third-born „	15·9	17·0
„ fourth-born „	12·4	12·3
„ fifth-born and later	30·0	22·0

It appears from this table that families in Toronto are much larger than those in Oakland, Cal. There are 26·4 per cent. of first-born children in Oakland as compared to 22·6 per cent. of first-born children in Toronto, while fifth- and later-born children form only 22 per cent. of the total population in Oakland, and in Toronto they form 30 per cent. This indicates that the size of the families is considerably smaller in Oakland as compared to those in Toronto. It is difficult to judge what the social causes of this phenomenon may be. The general conditions of life and the nationalities composing the population certainly have a great influence upon the size of the families. In order to investigate this question I have tabulated the Toronto girls according to their order of birth and the nationalities to which they belong. The results of this tabulation are given in the following table :—

Nationalities of Grandparents of Toronto Girls.

Order of Birth	English	Scotch	Irish	Canadian	American	German	French	Miscellaneous	Cases
1st	39·0	16·5	23·9	12·4	3·5	2·0	0·4	2·3	6,753
2nd	41·0	15·1	23·8	11·4	3·3	2·4	0·6	2·4	5,878
3rd	40·8	16·7	23·5	10·5	3·0	2·8	0·9	2·5	4,883
4th and 5th	44·4	17·1	23·6	7·3	2·7	2·0	0·4	2·4	6,728
6th and later	47·3	16·4	23·0	5·1	3·0	2·1	0·3	2·7	6,388
Total	42·5	16·4	23·6	9·3	3·1	2·3	0·5	2·5	30,630

That is to say, the percentage of Scotch, Irish, American, German, French, and miscellaneous grandparents remains the same for all the children, no matter what the order of their birth may be. There is, however, a fundamental difference in the distribution of English and Canadian children. Among the first-born children 39 per cent. of the grandparents are of English birth. Among the later-born children 47 per cent. are of English birth. This indicates that in families whose grandparents are of English birth we find a greater number of children than among the other nationalities. The reverse is the case among the Canadians. There is a decided decrease in the number of grandparents of Canadian birth among the later-born children. This indicates that the families of Canadian descent are small. It is very peculiar that these differences are found only among the English and Canadians, and that there are no differences in distribution among all the other nationalities.

This table is of importance also as showing that the difference in stature of first-born children and of later-born children cannot be ascribed to the influence of differences in nationalities. The change of proportion of English and Canadian blood in the grand total is so slight that we cannot possibly assume that it will materially modify the average stature of the people We may therefore safely say that the difference in stature of first-born and later-born children is not influenced by complications resulting from the influence of nationalities.

APPENDIX II.

Origin of the French Canadians. *By* B. SULTE.

We intend to explain the formation of a certain number of French people into settlers on the St. Lawrence during the seventeenth century, and from which has sprung the present French Canadian population.

(1) Acadia was peopled without any kind of organisation between 1636 and 1670, or thereabouts. No one has yet satisfactorily demonstrated where the French of that colony came from, though their dialect would indicate their place of origin to be in the neighbourhood of the mouth of the river Loire. They are distinct from the French Canadians in some particulars, and not allied by marriages with the settlers of the St. Lawrence.

Brittany never traded with Canada, except that, from 1535 to 1600, some of the St. Malo navigators used to visit the Lower St. Lawrence and barter with the Indians, but there were no European settlers in the whole of that pretended New France. Afterwards the *régime* of the fur companies, which extended from 1608 to 1632, was rather adverse to colonisation, and we know by Champlain's writings that no resident, no 'habitant,' tilled the soil during that quarter of a century. The men who were employed at Quebec and elsewhere by the companies all belonged to Normandy, and, after 1632, twelve or fifteen of them married the daughters of the other Normans recently arrived to settle for good. Brittany remained in the background after, as well as before, 1632. This is confirmed by an examination of the parish registers, where seven or eight Bretons only can be found during the seventeenth century.

(2) The trade of Canada remained in the hands of the Dieppe and Rouen merchants from 1633 to 1663. It consisted solely in fish and fur, especially the latter. Therefore any man of these localities who wished to go to Canada to settle there was admitted on the strength of the charter of the Hundred Partners, who were bound to send in people brought up to farming in order to cultivate the soil of the colony, but who did nothing of the kind, except transporting the self-sacrificing emigrants. There is even indication that the transport was not free. The other seaports of France having no connection with Canada before 1662, five or six families only came from these ports.

(3) When the business of the Hundred Partners collapsed about 1660, Paris and Rochelle came in for a certain share of interest, as they were the creditors of the expiring company, and soon we notice immigrants arriving from the neighbouring country places of those two cities.

The settlers (1633–1663) came, as a rule, individually, or in little

groups of three or four families related to each other, as many immigrants from various countries do at the present day.

From an examination of family and other archives, extending now over thirty years of labour, we make the following deductions :—

Perche, Normandy, Beauce, Picardy, and Anjou (they are here in their order of merit) contributed about two hundred families from 1633 to 1663, the period of the Hundred Partners' *régime.* By natural growth these reached the figure of 2,200 souls in 1663.

In 1662–63 there came about one hundred men from Perche and 150 from Poitou, Rochelle, and Gascony, with a small number of women. This opens a new phase in the history of our immigration by introducing Poitou and Rochelle amongst the people of the northern and western Province of France, already counting two generations in the three districts of Quebec, Three Rivers, and Montreal.

(4) After 1665 the city of Paris, or rather the small territory encircling it, contributed a good share. The whole of the south and east of France had no connection with Canada at any time. Normandy, Perche, Maine, Anjou, Touraine, Poitou, Saintonge, Angoumois, Guienne, and Gascony—on a straight line from north to south—furnished the whole of the families now composing the French Canadian people.

(5) From 1667 till 1672 a committee was active in Paris, Rouen, Rochelle, and Quebec to recruit men, women, and young girls for Canada. This committee succeeded in effecting the immigration into Canada of about four thousand souls. Half of the girls were from country places in Normandy, and the other half were well-educated persons, who did not go into the rural districts, but married in Quebec, Three Rivers, and Montreal.

Since these people were brought to Canada by the organised efforts of a committee, we might expect to find some detailed record of their arrival and origin, but as yet no such information is known to exist. We are merely told by contemporary writers of that period how many arrived at such and such a date, and the port of embarkation—that is all. Happily, the church registers, notarial deeds, papers of the courts of justice, and several classes of public documents show abundantly the places of origin of those who actually established their families here.

(6) In 1673 the King stopped all immigration, and this was the end of French attempts to colonise Canada. The settlers, of course, remained as they were, and in 1680 the whole population amounted only to 9,700 souls. Double this figure every thirty years, and we have the present French population of the Province of Quebec, Ontario, and that of the groups established now in the United States.

(7) The bulk of the men who came during 1633–1673 were from rural districts, and took land immediately on their arrival here. It is noticeable that a large number of them had besides a trade of their own, such as that of carpenter, cooper, blacksmith, so that a small community of twenty families possessed among themselves all the requirements of that kind that could be useful.

No land was given to those who did not show qualification for agricultural pursuits, and they were placed for three years in the hands of an old farmer before the title of any property was signed in their favour.

(8) In regard to troops disbanded in Canada at various dates much misunderstanding exists. The real facts are as follows :—Before 1665 no soldiers, therefore no disbandment; from 1665 to 1673 a few isolated

cases; the regiment of Carignan came to Canada in 1665 and left in 1669, with the exception of one company, which eventually was disbanded here; from 1673 to 1753 the garrisons of Canada consisted, as a rule, of about three hundred men in all, under an infantry captain, sometimes called the Major when no longer young.

Besides that 'detachment,' as it was called, an addition of six or seven companies was sent in the colony during the years 1684–1713, on account of the war. From 1753 to 1760 the regiments sent under Dieskau and Montcalm (seven-year war) do not seem to have left any number of men in the country. Therefore the 'military element' had very little to do in the formation of our French population.

(9) The date of the arrival of most of the heads of families will never be ascertained accurately. In order to face that difficulty with chances of success I have resorted to the following plan:—Prepare an alphabetical list of all the heads of families, and afterwards, when consulting the old archives and various sources of information, be careful in comparing your list with any date or other indication you may find. In this manner it turns out that a man was married in 1664 in Quebec, was a witness before the court in 1658, made a deed in 1672, in which he states that 'before leaving Alençon in 1652 to come to Canada.' . . . The date of '1652' and 'Alençon' are the very things I want; therefore I erase '1664' and '1658,' previously entered, and keep the oldest date, with the name of the locality. This process is slow but not the surest, but still it is the best yet found to reach a fair approximate estimate. Finally, I hope to publish that tabular statement in a couple of years from now.

(10) On the subject of uniformity of language, which is so remarkable amongst the French Canadians, we may observe that it is the best language spoken from Rochelle to Paris and Tours, and thence to Rouen. Writers of the seventeenth century have expressed the opinion that French Canadians could understand a dramatic play as well as the *élite* of Paris; no wonder to us, since we know that theatricals were common occurrences in Canada, and that the 'Cid' of Corneille was played in Quebec in 1645, the 'Tartuffe' of Molière in 1677, and so on. The taste for music and love for songs are characteristics of the French Canadian race. The facility with which they learn foreign languages is well known in America, where they speak Indian, Spanish, and English as well as their own tongue.

Anthropometric Measurements in Schools.—Report of the Committee, consisting of Professor A. MACALISTER (*Chairman*), Professor B. WINDLE (*Secretary*), Mr. E. W. BRABROOK, Professor J. CLELAND, *and* Dr. J. G. GARSON.

THE work done by this Committee during the past year has consisted solely in the distribution to applicants of the Rules for Measurement drawn up by the Committee, and in advising those responsible for physical measurements in schools as to points respecting which they had written for advice. A further supply of printed directions has been procured, the first set having become exhausted.

The Committee ask for their reappointment and for a further grant for printing and postage of 5*l.*, the grant for that sum received several years ago having been exhausted.

Ethnographical Survey of the United Kingdom.—Fifth Report of the Committee, consisting of Mr. E. W. BRABROOK (*Chairman*), Mr. E. SIDNEY HARTLAND (*Secretary*), Mr. FRANCIS GALTON, Dr. J. G. GARSON, Professor A. C. HADDON, Dr. JOSEPH ANDERSON, Mr. J. ROMILLY ALLEN, Dr. J. BEDDOE, Professor D. J. CUNNINGHAM, Professor W. BOYD DAWKINS, Mr. ARTHUR J. EVANS, Mr. F. G. HILTON PRICE, Sir H. HOWORTH, Professor R. MELDOLA, General PITT-RIVERS, *and* Mr. E. G. RAVENSTEIN. (*Drawn up by the Chairman.*)

1. THIS Committee was first appointed at the Edinburgh Meeting in 1892, upon the joint recommendation of the Society of Antiquaries, the Anthropological Institute, and the Folklore Society, for the purpose of organising local anthropological research, with the ultimate aim of establishing an ethnographical survey of the United Kingdom. In the paper in which the views of the three Societies were laid before the Association, it was acknowledged that so large and ambitious a scheme must take many years to perfect, and could only be proceeded with in detail. It was indeed hinted that in other countries no power short of that of the State would attempt to carry it out, and that in time it might be right to ask for State aid to do so in this country.[1]

2. It will be convenient, on the present occasion, to recapitulate the steps which the Committee has taken towards the fulfilment of the duty entrusted to it. The first was to invite the co-operation of delegates of the Royal Statistical Society, the Cambrian Archæological Association, the Royal Irish Academy, and the Dialect Society, in addition to those of the Societies already represented on the Committee. This invitation was readily acceded to, and the Committee has derived much help from the learned gentlemen nominated by the several bodies in question. Sub-Committees for Wales and for Ireland were formed.

3. The Committee next proceeded to consider and define the plan of its operations, which was to observe and record for certain typical villages, parishes, or places, and their vicinity—(*a*) the physical types of the inhabitants, (*b*) their current traditions and beliefs, (*c*) peculiarities of dialect, (*d*) monuments and other remains of ancient culture, (*e*) historical evidence as to continuity of race.

4. Such simultaneous observation and record appeared to the Committee to be the best means by which the object desired—that of studying the whole man and ascertaining what man is in any district—is to be obtained. It is necessary, not only to measure his skull and record his physical characters, but also to look up the history of his descent, find out

[1] *Journal of the Anthropological Institute*, xxii. 262.

from the remains of their workmanship what sort of people his forbears were, and ascertain what superstitions and beliefs they have transmitted to him.[1]

5. In the business of forming a list of places in the United Kingdom which appear specially to deserve ethnographic study, the Committee sought the assistance of a great number of persons possessed of local knowledge, and the substance of the correspondence is digested in the first and second reports of the Committee. They contain a large amount of interesting local information, and specify the names of more than 300 places as suitable for the survey.

6. It became the duty of the Committee, as a next step, to condense into a small and convenient pamphlet the instructions necessary to enable observers to conduct the survey on a definite and uniform plan. The volume of 'Notes and Queries on Anthropology,' prepared by another Committee of the British Association; the 'Handbook of Folklore,' published by the Folklore Society; the directions for the Archæological Survey, formulated by the Society of Antiquaries; and other publications, afforded ample material for this, but they were too voluminous for general use. The Committee has succeeded in reducing the necessary hints and instructions into a pamphlet of twelve pages, which has been found by experience sufficiently to indicate what is required.

7. Individual members of the Committee have rendered it excellent service by contributions to the study of the branches of the subject, which have been printed in appendices to its reports, viz., Mr. E. Sidney Hartland, the secretary, in his notes explanatory of the schedules, appended to the third report; and Mr. Laurence Gomme, in his paper on determining the value of folklore as ethnological data, appended to the fourth report.

8. The foundation having thus been laid, the Committee proceeded to take observations in detail, some of which have been published in the Reports, others in the transactions of local and other Societies, and others are reserved for examination and digest when further information has been obtained.

9. The following is a brief summary of the returns actually received from various parts of the United Kingdom up to the date of the Committee's last Report:—

England.—Suffolk (Miss Layard and others); Hertfordshire (Professor Haddon); Cambridgeshire (Professor Haddon); Lancashire (Rev. F. Moss); Yorkshire (Dr. E. Colley and others).

Wales.—Pembrokeshire (Mr. H. Owen and Mr. E. Laws).

Scotland.—Galloway (Dr. Gregor); Aberdeen (Mr. Gray).

Ireland.—The Aran Islands (Professor Haddon and Dr. Browne); Dublin (Dr. Browne); Inishbofin and Inishshark, co. Galway (Dr. Browne); Mayo (Dr. Browne).

10. A preliminary report on folklore in Scotland, by the Rev. Dr. Walter Gregor, formed Appendix III. to the Committee's fourth Report. Dr. Gregor had undertaken, at the request of the Committee, to make a special visit to certain districts of Scotland for the purpose of the survey. The remainder of his collections of folklore (items 168 to 734) are appended to this Report, and also an abstract of his measurements of the inhabitants.

11. In arranging the folklore for the Appendix to the present Report, all headings that could be dispensed with have been omitted, and where

[1] *Archæological Journal*, liii. 227.

consecutive items were collected at the same place the name of the place is only mentioned in the first instance instead of before every item, as in the previous Appendix, with the view of economising space as much as possible.

12. The Committee much regrets to record that Dr. Gregor, who was an accomplished observer, died on February 4th last, while actually engaged in his work on its behalf. The special qualifications which he possessed for that work, and the manner in which he set about and performed it, have impressed the Committee with a deep sense of the loss it has sustained. The Committee has endeavoured to express this in a communication which has been addressed to Dr. Gregor's family.

13. The collections contained in the Appendix to the present Report, added to those published in that to the fourth Report, will supply an excellent model for observers as to the manner of making and recording collections of folklore, and they are accordingly printed *in extenso*. It is not intended in future to print all such collections in the same manner, but to reserve them for digest and comparison as the work progresses towards completeness, and probably for publication either in local sources of information or in such combined form as may hereafter be found to be desirable, and be adopted with the approval of the Council of the Association.

14. The Committee has endeavoured to fill the place left vacant by the death of Dr. Gregor by the appointment of the Rev. H. B. M. Reid to carry on the work initiated by him, and it has also appointed the Rev. Elias Owen in Wales and Dr. Colley March in Dorsetshire as special observers in the same manner, these gentlemen having very kindly consented to devote their time to this work without remuneration, being guaranteed only the expenses they incur.

15. The Committee has also to acknowledge communications from Mr. F. W. Hackwood of observations taken in Wednesbury; from Dr. Andrew Dunlop, Dr. O. C. Powell, Mr. E. K. Cable, C.E., Mr. Nicolle, Mr. A. Collenette, and Mr. J. Le Bas, of observations relating to the Channel Islands; and from Mr. M. S. Hagen of observations in Ropley, Hampshire.

16. The Committee has also to thank the Hampshire Field Club for reprinting and circulating among the members of that club an extract from the pamphlet of questions issued by this Committee, and for passing a resolution to promote as far as possible in that county the work of this Committee.

17. Numerous other local societies have also shown a desire to co-operate with the Committee, which gladly and gratefully accepts their assistance.

18. It may be convenient, for the guidance of such workers as kindly volunteer their services in this manner, to mention some of the limitations of the work of the Committee.

19. With regard to the physical observations and measurements, and to photographs, it is not desired to obtain other than those which are typical of the district, and answer the rough test of having been free from intermixture with the inhabitants of other districts for at least three generations.

20. With regard to current traditions and beliefs or folklore, it is not considered necessary for this Committee to undertake the work on which the Folklore Society has embarked, of collecting and digesting for each county the folklore which is scattered over the numerous published works relating to the district. It will be sufficient if original observations are made and recorded upon the plan adopted by Dr. Gregor.

21. With regard to dialect, the Committee cannot better define its

limitations than by reference to the brief code of directions drawn up for the Committee by Professor Skeat and contained in the Committee's pamphlet.

22. With regard to monuments and other remains of ancient culture, the work of the Committee has been in some places anticipated, and in others is being carried on concurrently by the Archæological Survey set on foot by the Society of Antiquaries, and by that undertaken by the Cambrian Archæological Society. Where such survey has not been commenced, the Committee suggests that the method adopted by the Society of Antiquaries should be followed.

23. With regard to the historical evidences of continuity of race, where they exist in any publication, it will only be necessary to give a reference to that publication; but there will be great value in a full record of any that exist only in unpublished sources of information.

24. The duty which is entrusted to this Committee, and which is undertaken by those local bodies that have kindly interested themselves in its work, is necessarily so laborious, that the Committee is anxious that such local bodies should not burden themselves with any labour that can be avoided in the discharge of it.

25. The Committee would be glad if this intimation should have the effect of inducing other local bodies, that may possibly have been deterred from offering help by a feeling that the requirements of the Committee involve greater labour than such bodies are prepared to devote to the matter, to reconsider the position and undertake the essential portion of the work in the respective localities.

26. The Committee is prepared to provide any such local body and competent individual observers in any district with the necessary instruments for the physical measurements by way of loan, and with a proper equipment of forms of return, &c.

27. The whole of the grant appropriated to the Committee at the Liverpool meeting has not been expended, and the Committee asks to be reappointed and permitted to use the unexpended portion, with a further grant, so as to have placed at its disposal the sum of 50*l.* in all during the coming year.

28. A small amount of the sum allotted to Dr. Gregor for his expenses having been returned to the Committee unexpended has been surrendered to the Association.

29. The Committee has been glad to observe the commencement in Switzerland of an ethnographic survey under the management of the Swiss Folklore Society, upon lines very similar to those of this Committee.

30. In addition to the appendices already referred to, the following reports and tables are appended :—

A report by the Cambridge Committee, including statistics on the Physical Characters of the inhabitants of Barley, Hertfordshire, and the villages of Barrington and Foxton, Cambridgeshire; Tables of Physical Observations taken at Aberdeen, in Banffshire, and in the Island of Lewis; Tables of Physical Observations taken at Cleckheaton, Yorkshire; and a report by the Irish Committee relating to the valuable observations taken by Dr. C. R. Browne on Clare Island and Inishturk, co. Mayo. For all of these the Committee takes this opportunity of rendering its best thanks to the various gentlemen whose names appear in the appendices in question, and who have devoted much time and care to the collection and preparation of the statistics.

APPENDIX I.

Further Report on Folklore in Scotland.
By the late Rev. WALTER GREGOR, *LL.D.*

The Months.

168. *Kirkmaiden.*—If Feberweer be fair an clear,
There'll be twa winters in the year.

169. *Laurieston.*—If Feberuary blow fresh and fair,
The meal will be dear for a year and mair.

170. *Balmaghie.*—It is a custom to gather May dew (1st May) and wash the face with it.

171. *Kirkmaiden.*—Witches gathered May dew that they might work their incantations with it.

172. Witches were believed to make butter from May dew.

173. An old man named David Bell used to tell that going home early one May-day morning he saw three sisters, that had the reputation of being witches, drawing pieces of flannel along the grass to collect the dew. When the flannel was soaked, the moisture was wrung out. This took place about seventy years ago at a place called Thornybog.

174. *Dalry.*—Kittens brought forth in May are looked on as unlucky. They are commonly put to death.

174*a*. *Kelton.*—Miss —— of Dunmure House was found one May morning gathering the dew in a small tin jug. She intended to wash her face with it 'to make her bonnie.' (Told in Rerrick.)

Days of the Week.

175. *Kirkmaiden.*—It is unlucky to cut 'hair or horn' on Sunday.

176. *Borgue.*—If a child showed itself disobedient on Sunday, it was told it would be taken to 'The Man o' Moon.'

177. *Dalry.*—Any piece of work, as harvest, must not be begun on Saturday. Any work begun on that day will not be finished within the year.

The New Year.

178. *Kirkmaiden.*—It was a custom to cream the well at 12 o'clock at night on Hogmanay.

179. *Dalry.*—Some would not allow fire to be given out at any time.

180. *Kirkmaiden, Laurieston.*—A peat on fire would on no account be given out on the morning of New Year's Day.

181. *Ayrshire.*—It is accounted unlucky to give a live coal out of the house on the morning of New Year's Day to kindle a neighbour's fire. My informant's aunt did this one New Year's morning, and before the year was finished she lost a son. A second time she gave a live coal, and during the course of that year a daughter died.

182. *Kells.*—On Hogmanay great care was taken to keep the fire alive over night, as a neighbour would not give a live peat on New Year's morning to rekindle it.

182*a*. *Kirkmaiden.*—On Hogmanay the fire was 'happit' with more than ordinary care to keep it from 'going out,' as such a thing would be most unlucky, and also because no neighbour would give a live peat to

kindle it. On the same evening everything was made ready for the fire of the morning of the New Year.

183. *Kirkmaiden.*—Particular care was used to have everything prepared for the fire of the morning of the New Year.

184. No ashes were cast out on the morning of New Year's Day.

185. My informant's mother would not allow any water of whatever kind to be taken out of the house on New Year's Day. Others followed the custom.

186. *Laurieston.*—Nothing was put out of the house on the morning of New Year's Day.

187. *Kirkmaiden.*—My informant's husband, a farmer, would on no account give anything away on New Year's Day.

188. *Balmaghie.*—Nothing would be given in loan by some on New Year's Day.

189. *Portlogan.*—Some would not sell even a halfpenny-worth of milk on New Year's Day.

190. *Kirkmaiden.*—Something is brought into the house on the morning of New Year's Day before anything is taken out.

191. It was the custom till within twenty or twenty-five years ago for some member of the household to lay a sheaf or a small quantity of unthreshed grain on the bed of the father and mother on the morning of New Year's Day.

192. *Portlogan.*—It was the custom to throw a sheaf of grain on the farmer's bed on the morning of New Year's Day.

193. *Kirkmaiden.*—Some member of the family took a sheaf of grain and put a 'pickle' of it on each bed any time after 12 o'clock on the morning of New Year's Day.

194. My informant's father had the custom of throwing a 'pickle corn,' *i.e.*, a small quantity of unthreshed grain, on each bed on the morning of the New Year.

195. My informant's father was in the habit of bringing whisky with bread and cheese into each sleeping apartment and of giving each one a 'dram,' *i.e.*, a little of the whisky, along with some of the bread and cheese. He then went and gave a small quantity of unthreshed grain to each of the horses and cattle on the farm. After doing this he came back to the dwelling-house with a sheaf of unthreshed grain, and laid a 'pickle' of it over each bed.

196. *Portlogan.*—My informant was in the habit of giving a small quantity of unthreshed grain to each of the horses and cattle of the farm on the morning of New Year's Day, and wishing each a happy New Year, and saying to each as the fodder was given : 'That's your hansel.'

197. *Kirkmaiden.*—For the entertainment of the 'first fit' on the morning of New Year's Day and of other friends that may call during the day, is prepared 'chittert,' *i.e.*, pressed, and cooled so as to be fit to be cut in slices. This, along with bread and cheese, is placed on a table all ready for use.

198. Fish in some form or other used to be served up as part of the breakfast on the morning of New Year's Day.

199. On the morning of New Year's Day the boys used to go in companies to catch wrens. When one was caught its legs and neck were decked with ribbons. It was then set at liberty. This ceremony was called 'the deckan o' the wran.' My informant has assisted at the ceremony.

First Foot.

200. *Kirkmaiden.*—The fishermen of Drumore do not like a woman to enter their houses as 'first fit' on the morning of New Year's Day.

201. It is accounted unlucky to meet a barefooted woman as 'first fit' when one is going to fish.

202. My informant saw a fisherman of Portlogan meet his wife one morning as he was setting out for the fishing. He returned to the house and then set out again for his work.

203. *Kells.*—A man that lived in the parish of Kells used to say that, if in going to fish he met a certain woman that lived in Dalry, he might as well turn, for he would have no luck that day. My informant knew the man.

204. *Kirkmaiden.*—It is accounted unlucky to meet a woman as 'first fit' when one is going to shoot. It is especially unlucky if she is barefooted.

205. *Balmaghie.*—It is unlucky to meet a woman with flat feet as 'first fit.'

206. *Port Patrick.*—It is unlucky to meet as 'first fit' one with a squint-eye. It increases the unluck if there is red hair.

207. *Laurieston.*—A—— W——, an old woman that lived in Laurieston was reputed a witch. No one liked to meet her as 'first fit.'

208. *Dalry.*—A man that lived at the Ford House, Dalry, had the repute of having an 'ill fit.' One day he entered a house in Glenlee as a woman was churning cream. When he left the house she cast some salt into the fire.

'Can'lesmas Bleeze.'

209. *Laurieston.*—The scholars assembled in the schoolroom. The roll was called, and as each one's name was called out, he or she went forward to the teacher's desk and laid down a piece of money. There was a contest between a boy and a girl who was to be king or queen, and the teacher knew beforehand who were to contend for the honour. Their names were called out last. They went to the teacher's desk as the others did and laid down a shilling (about). The one that laid down for the longest time was king or queen as the case might be. Whisky toddy, weak and sweet, was then given to each scholar. Sometimes oranges and other good things were added. Then followed a dance. My informant, when a scholar, used to supply the music from a fiddle, and for years after he left school. Parents, scholars, and friends were at times entertained at a dance in the evening. Next day was generally given as a holiday to the scholars. When the custom fell out of use a present was made to the teacher about Christmas. The custom of making a present at Christmas continues.

[The Rev. H. M. B. Reid notes upon this :—'The arrangements were made a few days before February 2 (Candlemas). If February 2 fell on a Sunday, the next day after was kept. In Glenlochar School (Balmaghie) the king and queen were *not* known beforehand (schoolmaster's widow, aged 79).']

210. *Balmaclellan.*—As each scholar came into the schoolroom he or she went to the teacher's desk, and laid down his or her gift. The scholar's name and the amount of the gift were recorded. When all had brought their gifts, the teacher called out the name of the girl that had given the

largest sum among the girls. She was styled queen. He also called out the name of the boy that had given the highest sum among the boys. He became king. Whisky toddy was then prepared. The teacher then gave a glass of it to the king and queen—each. The king then poured into glasses from a jug the toddy and handed them to the other scholars, whilst the queen kept the jug filled from the bowl in which it had been made. There might be one hundred and twenty scholars at Balmaclellan school, and the quantity of whisky used was a bottle, so that the toddy was weak. It was made very sweet. (Told by one who was a scholar at this school, and who has been treated to the toddy.)

211. After the drinking of the toddy the scholars engaged in various kinds of games. In later times a 'bake' or biscuit was given, in addition to the toddy, to each scholar. (Told by one who was a scholar and had taken part in the feast.)

212. A 'bake' was given to each scholar in addition to the toddy. Sometimes the scholars engaged in dancing. (Told by one who has been an actor.)

213. *Corsock.*—My informant attended a small school at Merkland, Corsock. The same custom was observed at it. Each scholar, as he or she entered the schoolroom, laid down his or her gift. When all had presented their gifts, a glass of weak toddy was served to each scholar. Toasts were at times given by some of them. My informant gave the following :—

'Here's health, wealth, wit t' guide it,
Ower my throat I mean t' guide it.'

214. *Kirkmaiden.*—It was a custom not long ago to bring something into the houses on the morning of Candlemas Day before taking anything out.

Hallowe'en.

215. *Balmaghie.*—The following mumming-play is performed by the school children at Hallowe'en :—

There are seven actors, three of whom carry sticks or swords.

(1) Bauldie, wearing a 'fause face' (a mask), commonly black, dressed in a big coat, and carrying a stick as a sword ; ordinary cap on head.

(2) The Captain, dressed in the same way.

(3) The General, dressed in the same way.

(4) The Doctor, wearing a mask, black with red spots on chin, cheeks, and brow, with a big 'tile' hat on head, a stick in one hand, and a bottle of water in the other.

(5) Peggy—face painted white—wearing an old dress down to her heels, an old mutch, with an old umbrella in hand.

(6) Policeman—face painted black, with no red spots, wearing a big black coat, a big brown paper bag on his head, with a stick in his hand.

(7) Weean—face painted white, wearing a small frock, and ordinary hat with ribbons.

All except the Doctor enter the kitchen. They are asked 'What do you want?' They answer by singing 'Gentle Annie' or any other school song. Then speaks—

Bauldie: Here comes I, Bell Hector ;
Bold Slasher is my name.
My sword is buckled by my side,
And I am sure to win this game.

General: This game, sir! This game, sir!
It's far beyont your power.
I'll cut you up in inches
In less than half an hour.
Bauldie: You, sir!
General: I, sir!
Bauldie: Take out your sword and try, sir!
[*They fight; the* GENERAL *is killed.*
All: The Doctor.
[*One runs and calls the* DOCTOR.

The DOCTOR *enters.*

Doctor: Here comes I, old Doctor Brown,
The best old Doctor in the town.
All: And what diseases can you cure?
Doctor: I can cure all diseases, to be sure.
All: What are they?
Doctor: Hockey-pokey, jelly-oakey,
Down amongst the gravel.
[*The* DOCTOR *gives the* GENERAL *a draught from the bottle, and he starts to his feet.*]

216. *Laurieston.*—The following version is played here:—

HECTOR, SLASHER, *the* DOCTOR, BEELZEBUB. *Three of the actors enter the house and say:*

Hallowe'en, Hallowe'en comes but once a year,
And when it comes we hope to give all good cheer.
Stir up your fires, and give us light,
For in this house there will be a fight.
Hector: Here comes I, bold Hector;
Bold Hector is my name.
With my sword and pistol by my side
I'm sure to win the game.
Slasher: The game, sir! The game, sir!
It's not within your power;
For I will cut you up in inches
In less than half an hour.
Hector: You, sir!
Slasher: I, sir! [*They draw swords and fight.*
Hector. Do, sir; die, sir! [SLASHER *falls.*
Hector: Oh, dear! what's this I've done!
I've killed my brother's only son.
A Doctor! A Doctor! Ten pounds for a doctor!
What! No doctor to be found?

DOCTOR *enters.*

Doctor: Here comes I, old Doctor Brown,
The best old Doctor in the town.
Hector: What diseases can you cure?
Doctor: All diseases, to be sure.
I have a bottle by my side,
All mixed with polks (?) and eggs;

Put it in a mouse's blether,
Steer it with a cat's fether;
A drop of it will cure the dead.
[*Some of the medicine administered to* SLASHER

Hector: Get up, old Bob, and sing a song.
[SLASHER *jumps up.*

Slasher: Once I was dead and now I'm alive;
God bless the old Doctor that made me survive.

BEELZEBUB *comes forward.*

Beelzebub: Here comes I, old Beelzebub,
And over my shoulder I carry my clogs,
And in my hand a frying-pan;
So don't you think I'm a jolly old man?
And if you think I am cutting it fat,
Just pop a penny in the old man's hat.

217. Another version:—

HECTOR, SLASHER, *the* DOCTOR, JOHNNY FUNNY.

Hector: Here comes I, bold Hector;
Bold Hector is my name;
A sword and buckler by my side,
And I'm sure to win the game.

Slasher: Here comes I, bold Slasher;
Bold Slasher is my name;
A sword and buckler by my side,
And I shall win the game.

Hector: You, sir!

Slasher: I, sir!

Hector: Take out your sword and try, sir!
[*The two fight, and* HECTOR *falls.*

Slasher: Oh dear! Oh dear! what's this I've done?
I've killed my brothers all but one.
A doctor, a doctor, ten pounds for a doctor!

The DOCTOR *enters.*

Doctor: Here comes I, old Doctor Brown,
The best old Doctor in the town.

Slasher: What diseases can you cure?

Doctor: All diseases, to be sure—
Gout, skout, bully gout, and the carvey.
[*Administers medicine to* HECTOR.

Slasher: Rouse up, sir; sing us a song.

HECTOR *rises.*

Hector: Once I was dead, and now I'm alive;
God bless the Doctor that made me survive;
Up and down the mountains, underneath the ground,
Eating bread and biscuits all the year round.

JOHNNY FUNNY *enters.*

Johnny Funny: Here comes I, wee Johnny Funny,
The very wee boy to gather the money;
Pouches down to my knees,
And I'm the boy to gather the bawbees.

218. *Balmaghie.*—At Hallowe'en the children carried one lantern made of a hollowed-out turnip, and called at the houses and got apples, hazel-nuts, money (which was divided), potatoes, mashed, with a sixpence among them (this last at a cotman's house). The sixpence was divided.

[It may be mentioned that in Forfarshire the children sang, swinging the hollow *neip*, or turnip :—

Hallowe'en, a night at e'en,
A candle an' a kail-runt ! [1]]

The visits lasted from 7 to 9 P.M., and covered a dozen houses. Some locked the door, but usually the people were glad to see them.

The Moon.

219. *Kirkmaiden.*—'Faul' is a name for a halo round the moon. The weather proverb is, 'A far-aff faul is a near-han' storm.'

220. A halo round the moon is called a 'broch.' There is commonly an opening in it, which is called the 'door.' The weather proverb is, 'A far-off broch, a near shoor.'

221. *Borgue, Dalry, Kirkmaiden.*—The spots on the moon are formed by the man that gathered sticks on the Sabbath. He was transferred to the moon, with his bundle of sticks on his back, as a punishment for Sabbath-breaking.

222. *Portlogan.*—The mairt used to be killed when the moon was on the increase.

223. *Kirkmaiden.*—If a hen is set when the moon is on the increase it is believed that the birds are hatched a day earlier than if she is set during the time of waning.

224. *Portlogan.*—A sow brings forth as many pigs as the moon is old at the time she conceives.

225. *Kirkmaiden.*—Flax had to be steeped at such a time as that the moon would not change while it lay in the 'dub,' or 'lint-dub.' It was believed that if a change did take place the mucilage became thick and the fibre was injured. To counteract this evil a piece of iron was thrown into the 'dub' among the flax.

226. On seeing the new moon for the first time an unmarried woman repeats the words :—

All hail to the muin, all hail to thee !
I pray thee, guid muin, come, tell to me
This night who my true love's to be.

Without speaking a word [afterwards] she goes to bed. She dreams of the lover that will wed her.

227. *Dalry.*—The first time a woman sees the new moon, she has to curtsey to her.

228. *Mochrum, Dalry.*—It is unlucky to see the new moon for the first time 'through glass,' *i.e.*, through a window.

229. *Balmaghie.*—If the new moon is lying on her back 'the rain does not get through,' and so there will be fair weather. If she stands straight up and down all the rain runs off, and so the weather will be wet.

[1] Kail-runt = cabbage-stalk.

230. *Rerrick.*—The circle round the moon is called a 'ring.' It indicates a change of weather. The saying is—

The farder oot the ring
The narder han' the storm.

231. *Corsock.*—The halo round the moon is called a 'faul' (fold). It is an indication of a coming storm. The open space in it lies in the direction from which the storm will blow.

232. *Rerrick.*—The circle round the moon is called a 'broch.' It is looked on as an indication of a change of weather.

233. *Corsock.*—When one sees the new moon for the first time, let the money in the pocket be turned and three wishes formed, and they will be fulfilled.

234. *Dundrennan.*—Cabbage-seed must be sown in the waning of the moon, else the plants will run to seed.

The Sun.

235. *Corsock.*—If at sunrise the sky becomes red, and the red extends far over the sky, the day will be fine; but if the red remains low, and disappears soon after sunrise, rain follows in a short time.

236. *Kirkmaiden.*—A mock sun is called a 'dog.'

237. *Dundrennan.*—A glassy glittering sunset is an indication of a breeze.

Thunder.

238. *Minnigaff, Balmaghie.*—During a thunder-storm some are in the habit of opening the door and windows of the dwelling-house, with the idea of allowing the lightning to escape if it enters the house.

239. *Balmaghie.*—The fire is taken out of the grate. Sometimes it is extinguished with water.

240. *Kirkmaiden, Minnigaff, Balmaghie.*—It is usual to cover up all looking-glasses.

The Dwelling-house.

241. *Kirkmaiden.*—When the foundation of a house is laid, the workmen are entertained with whisky. This whisky is called the 'funin pint,' *i.e.*, foundation pint.

242. When the carpenters begin to put on the roof of a house, they receive at times whisky. This is called the 'reefin pint,' *i.e.*, roofing pint. (Informant a carpenter.)

243. *Dalry.*—It is unlucky for one to build a house to live in.

244. *Kirkmaiden.*—My informant has heard it said that it is unlucky for one to build a house to live in.

245. *Dalry.*—It is not lucky for one to enter for the first time by the back-door a house he (she) is to live in.

246. *Balmaghie, Kirkmaiden.*—The floor of the dwelling-house must never be swept towards the door, but towards the hearth.

247. *Kirkmaiden.*—The hearthstone is accounted the most sacred part of the dwelling-house.

248. *Kells.*—When Kirkdale House, in the parish of Anwoth, was built, the man that laid down the first load of stones for the building of it was hanged for the murder of a woman whom he had led astray, and the mason that laid the first stone of it was killed in the course of its

erection. The common explanation of these fatalities was that the owner of the house had gained his fortune by unjust means.

249. Kenmure Castle, in the parish of Kells, was planned to be built on an island in Loch Ken, and a quantity of stones was laid down for its building. During one night before the work was begun, they were all taken away and laid down on the site the Castle now holds. (Told in Balmodellan.)

250. In a holm on the river Ken near Kenmure Castle there is a large block of stone. It was thrown from Cairne Edward by the devil to destroy Kenmure Castle. He put too much force into his cast, and the rock went over the Castle and fell on the holm beyond it.

251. *Rerrick.*—When the old church of Rerrick was being taken down, the aunt of the wife of the man that had contracted to do so remonstrated with her for allowing him to undertake the work. He or another of the workmen, she said, would be killed. A beam fell upon him and injured him.

252. *Kirkmaiden.*—In flitting into a house that has been left vacant by another, no one enters it without first casting into it a living creature, commonly a cat or a hen. If 'ill has been left on the house,' it falls on the animal that is thrown into it. It dies, and the lives of those that are to dwell in the house are spared.

253. A family at Aachliach, when removing, bore a grudge against those that were to occupy the house after them. They swept the hearth and the house clean, and put on 'a stone fire.' Something had been forgotten in the house, and a daughter returned to fetch it. The 'ill that had been left on the house' fell on her. She became a cripple, and for many years was able to walk only on crutches.

254. *Rerrick.*—In going into a house from which another person or family has removed, it was usual to cast into the house a living creature, as a cat or hen, before any of the family entered.

255. If one, on leaving a house, had a grudge against those that were to live in it, the house was swept clean and a fire of stones and green thorn was placed on the hearth.

256. A family of the name of Burnet went into a house at Holehouse, from which had gone out another family that bore an ill-will against the new tenants for putting them from the house. The fire of stone and green thorn had been placed on the hearth. The usual precaution of casting in a living creature had been omitted. The youngest son was the first to enter the house. 'He did nae guid aifter,' *i.e.*, he fell into weak health. My informant has heard the young man's brother tell the story.

257. My informant's daughter was removing from a house. To leave the house as neat as she could for those that were to occupy it after her, she swept the floor of the house, lifted the sweepings, and cast them out. The man that was to inhabit the house was present. Seeing what she did, he called out, 'Ye bitch, why did ye soop awa ma luck ?'

Meal.

258. *Balmaghie.*—The 'kist,' or box in which the meal is kept, is called the 'ark' or 'meal-ark.'

259. *Laurieston.*—Said a woman aged eighty-five, 'The meal is beetlt doon i' the meal-ark till it is firm an' sad.'

Bread.

260. *Tungland.*—The whisk used for brushing the dry meal off the cakes is called 'the sooper,' and is made of the wing-feathers of domestic fowls.

261. *Kirkmaiden.*—In rolling out a cake, if a hole broke open in it, it is augured that strangers will eat of it.

262. *Minnigaff.*—If the cake breaks in the rolling out, it is an omen that strangers will turn up to have a share in eating 'the bakan.'

263.—In baking a cake, if the 'crown of the farle' breaks, it indicates that strangers will eat of that bread.

264. *Galloway generally.*—The cake is commonly cut into three 'farles.'

265. *Kirkmaiden.*—To find out whether the cake is sufficiently 'fired,' it is usual to lift the 'crosn o' the farle.' If it breaks when lifted, it is taken as an omen that the death of a near relative is at hand.

266. When the crown of the 'farle' breaks during the course of baking, the death of a friend will be heard of before the 'farle' is eaten.

267. *Balmaclellan, Rerrick, Laurieston, Dalry.*—If the crown of the 'farle' breaks in the course of baking, it is regarded as a portent of a death at no distant period.

268. *Tungland.*—If the crown of the 'farle' breaks when taken off the 'girdle,' a death will soon be heard of.

269. *Dalry.*—When the 'girdle' is taken off the fire and laid on the floor after baking is finished, and before being laid aside, a scone or 'farle' is left on it to keep off ill-luck.

270. *Minnigaff.*—The hollow side of the 'farle' is placed uppermost.

271. *Kirkmaiden.*—It is considered by some to savour of bad 'farle' to 'nip the croon o' the farle' in eating it, *i.e.*, to begin to eat the manner from the top or crown.

272. *Minnigaff.*—By many it is accounted bad manners to break off the crown of the 'farle' first when one begins to eat it.

273. *Rerrick.*—It is accounted unlucky to begin to eat from the 'croon o' the farle.'

274. *Laurieston.*—Said an old woman to me: 'A "melder bannock" was made for the wee yins.'

275.—A kind of bannocks, called 'treacle bannocks,' used to be made for use about the New Year. They were composed of oatmeal with treacle added. Sometimes carraway seeds were added.

Mills.

276. *Kells.*—It is unlucky to pull down a meal mill.

277. My informant's uncle was a miller. He was put out of his mill by a family of Maxwell. J. McQueen, a neighbour, said that 'they widd a' gang like braxy sheep. Nae boddie widd doe ony guid that knockit doon a mortart (moultert) mill.' The family afterwards went to ruin. The meal-mill was turned into a saw-mill.

278. 'They never thrive that middle wi' kirk or mill.'

279. There was no milling on New Year's Day, 'except when thrang.'

Trades.

280. *Balmaghie.*—When an apprentice to the shoemaking trade 'sat doon,' 'he paid his fittan'—*i.e.*, he gave a quantity of whisky to the tradesmen in the shop.

281. When the apprenticeship was finished, there was 'the prentice lowsan'—*i.e.*, there was a feast, a 'high' tea with a little drinking of whisky. A dance completed the festivity. What money was left over was given to the young man to help him to make a start in life. Till lately this was quite a common custom.

282. Shoemakers were, at one time, in the habit of going to the houses of their customers to exercise their calling. This was called 'tc boag.'

283. The higher that a plum-tree grows,
The richer grows the plum;
The harder that a poor snob works,
The broader grows the thum'.

(All told by a shoemaker.)

284. *Dundrennan.*—It was the custom, when a shoemaker finished his apprenticeship, for his companions and friends to give a ball. It was called 'the lousin ball.' My informant has seen such balls.

285. *Balmaghie.*—Saddlers were, at one time, in the habit of going to the houses of their customers to do their work.

286. *Portlogan.*—A bottle of whisky was always carried to the smithy when a horse was to receive his first set of shoes.

287. *Kirkmaiden.*—A bottle of whisky was given to the blacksmith when he put on the first set of shoes of a young horse. Part was drunk when the first nail was driven.

288. *Mochrum.*—When a young horse was brought to the smithy to be shod for the first time, the blacksmith, before driving the first nail, 'sounded' the foot by striking it with the hammer.

289. *Portlogan.*—In welding two pieces of iron, if they 'misst the heat,' and did not weld, some barley-straw was got, laid on the ground round the 'studdy,' and burned. The two pieces of iron were again laid in the fire to 'tack the heat again' for welding. My informant has seen this done.

290. No regular blacksmith could be induced to make the nails for the crucifixion of our Saviour. A travelling blacksmith did so. The tinkers have wandered ever since. (Communicated chiefly by two blacksmiths.)

291. *Corsock.*—It was the custom to drink whisky on the occasion of a young horse getting the first set of shoes. If the first nail driven went straight, the blacksmith used to say: 'The whisky's win.' If the nail did not go straight, it was thought the blacksmith had not fairly won his 'dram,' for it might be refused. Though the custom has, for the most part, been given up, the blacksmith will sometimes say when he drives the first nail straight: 'The whisky's win.'

292. *Girthon.*—When an apprentice blacksmith finished his apprenticeship, his companions and friends sometimes gave a ball, called 'the lousin ball.' The apprentice gave no money for its expenses, and if there was any money over, after paying the expenses, it was given to the apprentice.

293. *Mochrum.*—When a toast is proposed to a carpenter, a form of words:—

'Here's to pottie, paint, and glue.'

294. *Portwilliam.*—It takes nine tailors and a bull-dog to make a man. Here is one explanation of the saying. Nine tailors that in

common harassed a bull were asked for alms by a tramp. Each gave him a little. The tramp turned from his begging, entered into some sort of business, and made a fortune, and so became a 'man.'

295. Another explanation, differing in some respects from this, was communicated by a tailor.

296. *Kirkmaiden.*—When an apprentice gardener completed his apprenticeship, his companions gave him a ball called the 'lowsan ball.'

297. *Dundrennan, Parish of Rerrick.*—Weavers did not weave on New Year's Day.

The Clergy.

298. *Borgue.*—It is unlucky to speak ill of a minister.

299. *Balmaghie.*—It is unlucky to speak ill of a minister, or to do him any harm. Once a few men would play a trick on a minister, and they contrived to induce him to take strong drink till he was overcome. This act caused a scandal, and the minister was charged with drunkenness before the Presbytery by libel. The men that had been the cause of his slip were summoned as witnesses. All of them were ill and confined to bed when the trial came on, so that not one of them was able to appear at the court to give evidence.

300. 'Nae boddie it conters a minister comes t' a guid en'.'

301. 'Ministers are black craws t' sheet at.'

302. 'Hae ye a dog, Maister Reid?' asked a man one day of Mr. Reid.

'No. Why do you ask?'

'It's an aul story here, the minister's dog aye barks at them it dinna come aften t' the kirk.'

303. *Kells.*—'It is unlucky t' middle wi' craws an' ministers.'

Cattle.

304. *Dalry.*—In spring the cattle of a farm used to be bled. Part of the blood was baked into a kind of bread (oaten) called 'bleed scones.'

305. *Kirkmaiden.*—About sixty years ago all the cattle were bled in spring. The blood was preserved, and cooked as food. A little was mixed with it.

306. *Balmaghie, Crossmichael.*—A stone whorl or 'bort stone' is placed by some over the byre door inside, to keep off witches.

307. *Crossmichael.*—Cattle were rubbed over with a 'bort stone' to ward off disease.

308. *Penninghame.*—A 'holt stone,' *i.e.*, a stone with a natural hole or cavity in it, or 'bort stone,' *i.e.*, a stone whorl, was kept in the watering trough of the cattle. Sometimes the guidwife took a besom, whisked it round and round the trough, and then sprinkled some of the water over the cattle as they stood round the trough.

309. In the cattle-watering-trough on the farm of Garchew, in the parish of Penninghame, a 'holt stone' was kept for the protection and luck of the cattle. It was called 'Old Nanny's mother's trough stane.' Old Nanny Wilson died about 1891, at the age of ninety years.

310. *Corsock.*—Sometimes the nose of a cow, stot, or calf will swell. The animal is said to be 'weasel-blawn.' It is supposed the swelling is caused by the bite of an adder. If there are any feathers in the house, they are taken and placed under the animal's nose, and set on fire. The

smoke is supposed to effect a cure. If there are no feathers available at the time, a fowl is killed without delay and plucked, and the feathers are used.

311. *Kirkmaiden.*—Before the cows were put forth to grass for the first time in spring, some had the custom of sprinkling over them a mixture of salt and urine that has been long kept, and thus smelt strongly.

312. *Dalry.*—Sixty years ago my informant has seen fire put down in the byre-doorway on Beltane, and the cows were made to pass over it.

313. *Corsock.*—It is the belief that, if a cow or a ewe, immediately after coition, gets a fright from any object, the offspring is of the same colour as the object that causes the fright. John McKie at Drumhuphry, Kirkpatrick-Durham, was one day leading a black Galloway cow from the bull, when a white animal jumped a hedge near the cow. She took fright. The offspring of the cow was white.

314. *Kirkmaiden.*—A little salt used to be put by some on a cow's back when bought.

315. If a cow began to tremble, it was believed she had been struck with a fairly shot. A wise woman was sent for, and she carefully groped over the animal's body for the hole made by the shot. A cure was a quantity of soot, salt, and butter made up into three balls, and put down the animal's throat.

316. A man's cow became ill and fell down. A 'skeely' woman was sent for. She came and rubbed the animal all over with an 'elf-shot.' The animal jumped up as if nothing had been the matter.

317. *Corsock.*—If a cow did not give her milk, some feathers were taken from a pillow or bolster, placed before her, right under her nose, and set fire to, so that she might inhale the smoke.

318. *Kirkmaiden.*—A byre-girl sprinkles her urine over a cow's back when she is going to calve. This is done to keep off witches and ill-luck. Not long ago a farmer's widow ordered her byre-girl to do this.

319. When a cow dropped the calf, a little salt was placed on her back.

320. *Tungland.*—Some salt or oatmeal was put on the cow's back over the 'neers,' *i.e.*, kidneys, when she dropped the calf.

321. *Kells.*—My informant's mother used to put a little oatmeal on the cow's back after the calf was dropped.

322. *Tungland.*—When a cow calved, oatmeal and salt mixed together were sprinkled along the cow's back and over the calf.

323. *Balmaghie.*—A mixture of oatmeal and salt was put on the cow's back over the kidneys when she dropped the calf.

324. *Tungland, Kirkmaiden.*—Beesnan is the name of the milk first drawn from the cow after calving. Part of it is at times given to the cow.

325. *Kirkmaiden.*—When the cow calved, a little salt was, and is still, put by some into the pail into which the milk is drawn. (From more than one informant.)

326. My informant has seen a sixpenny piece put into the pail into which a cow was milked the first time after calving. (More than one informant.)

327. Part of the milk of newly-calved cows is cooked into a dish

called 'Beesnan cheese.' Pancakes, called 'Beesnan pancakes,' are at times made of it.

328. A little salt was put into the churn when butter was being made to keep off witch-spells. (Informant eighty-one years of age.)

329. When cream was long in coming, some had the custom of putting a sixpenny piece into the churn or under it.

330. Some had the custom of drying a newly calved calf with 'shillin-sids.'

331. *Balmaghie.*—A little of the cow's droppings was put into the calf's mouth when it came from the cow.

332. *Kirkmaiden.*—Some put an egg into the calf's mouth when dropped from the cow.

333. *Tungland.*—The calf gets part of the 'beesnan.'

The Horse.

334. *Kirkmaiden.*—A mare was always foaled outside if possible. If foaled inside, the foal when grown would lie down when passing through a ford, or break a man's leg.

335. It was accounted unlucky if a mare foaled inside the stable.

336. *Portlogan.*—Twa white feet you may buy,
But three never try.

337. *Corsock.*—Mares are still foaled outside, except in early spring if the weather is too cold.

338. Some keep whistling during the time a young horse is being shod for the first time. It is thought the whistling keeps the animal quiet.

338*a.*—Some farmers had the custom of carrying a sheaf of oats to the smithy when they took a young horse to receive the first set of shoes. When the shoes were being put on they kept feeding the animal with handfuls of the grain, under the idea that this kept it quiet.

339. A young horse commonly gets its name when it is between two and three years old, when one begins to train it to work. (My informants are blacksmiths in Corsock.)

340. *Kelton.*—My informant in 1894 went into a cot-house in the parish of Kelton. As he was entering he observed a horse-shoe placed on the ground at each side of the door. He asked the cot-man's wife what she meant by having them there, and where she got them. She said: 'We brocht them frae oor last place in Borgue, and they are a pair o' the shoes o' the pair o' horse my man drove, an' as lang as they are there, we'll keep oor place.' 'But if one was t' steal them, what would happen?' said my informant. 'Then we'll no be lang here,' was the answer.

341. *Kirkmaiden.*—An old horse-shoe is sometimes nailed to the inside of the byre-door to bring luck.

342. *Rerrick.*—The skeleton of a horse's head was found below the pulpit when the old parish church was pulled down.

Sheep.

343. *Kirkmaiden.*—About forty years ago it was the custom to put a little salt in the mouth of the lamb when it fell from the ewe. This was supposed to cleanse the mouth.

344. Sheep before a change of weather always leap and frisk, and box (butt) each other.

Pigs.

345. *Tungland.*—A sow, when she farrows, gets a farle of bread (oaten) and butter.

346. *Kirkmaiden.*—Some would allow only one with dark eyes to look for the first time on a young pig when brought home. One woman would not permit any one to look on the young pig she brought home till Betty McMaster with her black eyes looked on it.

The Cat.

347. *Balmaghie.*—A black cat not belonging to the house coming in is looked upon as unlucky.

The Hedgehog.

348. *Balmaghie.*—To meet a live hedgehog in the morning is regarded as an omen of good luck.

349. To come across a dead hedgehog is deemed unlucky.

The Hare.

350. *Balmaclellan.*—It is unlucky to meet a hare.

351. *Balmaghie, Rerrick.*—It is deemed unlucky if a hare crosses the path in front of one.

352. *Corsock.*—A man of the name of McGeorge, if he had been going to fetch home a young pig to rear and had met a hare, was wont to turn back. He believed the pig would not thrive if brought home that day.

353. *Port Patrick.*—A fisherman accounts it unlucky to meet a hare when he is going in the morning to 'fish his net' (salmon). 'We needna gang, boys, there she is,' says a fisherman to his companions, if such a thing happens. He does not utter the word 'hare.'

354. *Rerrick.*—A hare running along the street of the village of Dundrennan is looked upon as very unlucky. Some years ago a hare ran along the street. Not long after an epidemic broke out, but my informant did not remember what epidemic it was.

355. *Borgue.*—It is deemed unlucky to meet a hare in the morning.

356. *Kirkmaiden.*—If a fisherman in going to the fishing meets a hare he will turn and go back, as there will be no luck that day.

The Wild Rabbit.

357. *Balmaghie.*—Some account it unlucky to meet a wild rabbit.

Domestic Fowls.

358. *Rerrick, Kirkmaiden.*—A cock crowing at the door forebodes the coming of a stranger.

359. *Kirkmaiden.*—It was at one time a belief that if a cock reached the age of seven years he laid an egg, which, when hatched, produced a cockatrice.

360. *Kirkmaiden.*—It is an indication of a coming misfortune if a cock crows at night.

361. *Balmaclellan.*—If the cock goes crowing to bed, he'll rise wi' a watery head.

362. *Crossmichael.*—When a cock crowed at what was looked upon as an untimely hour, the guidwife rose from bed, went to the hen-house,

opened the door, and light in hand looked in what direction the bird was looking. That direction indicated the direction from which some piece of bad news was to come.

363. *Kirkmaiden.*—When a hen crowed she was killed at once. Such a thing was accounted very unlucky. 'A crawin' hen's no sonsey' and 'A crawin' hen an' a whisslin' lass is no sonsey' and 'Whisslin' maidens an' crawing hens are no lucky aboot ony man's hoose,' are three saws.

364. *Kirkmaiden.*—The small egg a hen sometimes lays bears the names of a 'nocht' and 'a mock.' Such an occurrence is regarded as the forerunner of some piece of misfortune.

365. *Minnigaff.*—The first egg a hen lays is called a 'maiden egg.'

366. *Kirkmaiden.*—A hen is set in the evening after sunset.

367. *Portlogan.*—A hen is not set during the month of May. The saying about chickens hatched in May is :

Come oot in May
Moom for aye.

368. *Portlogan.*—A hen hatches as many chickens as the days of the moon's age when she is set.

369. *Kirkmaiden.*—A hen is set with an odd number of eggs, commonly thirteen.

370. *Kirkmaiden.*—If the tread is right on the top of the egg, a cock-bird is hatched, if it is towards the side a hen-bird comes forth.

371. *Kirkmaiden.*—If a black spot is painted on the egg of a white hen before it is placed for hatching, the bird hatched will have a black spot.

372. *Balmaclellan.*—It is considered unlucky if a hen lays a very small egg. Guidwives did not like to get such an egg.

373. *Balmaclellan.*—A hen is set in the gloaming with the number of thirteen eggs.

374. *Laurieston.*—It is unlucky to have a crowing hen about the house.

Sea-birds.

375. *Kirkmaiden, Balmaghie.*—When sea-birds fly inland, a storm is approaching.

376. *Mochrum.*—The cormorant bears the name of Mochrum Elder.

377. *Rerrick.*—The cormorant is called Colvend Elder.

378. It is accounted unlucky by some to shoot a cormorant.

The Swallow.

379. *Balmaghie.*—If swallows come to a house it is accounted lucky.

380. *Kirkmaiden.*—It is unlucky to do harm to a swallow's nest.

381. *Dalry.*—It is unlucky to injure swallows in any way.

382. *Kirkmaiden.*—

Sit and see the swallow flee,
Gang and hear the gowk gell,
The foal afore its mither's ee,
An that 'ill be a guid year for thee.

383. *Borgue.*—It is unlucky to shoot a swallow.

The Wren.

384. *Kirkmaiden, Balmaghie.*—It is unlucky to kill a wren.
385. *Balmaghie.*—It brings ill luck to harry a wren's nest.

The Robin.

386. *Balmaghie, Kirkmaiden.*—It is accounted unlucky to kill a robin
387. *Balmaghie.*—

The robin and the wran
Sits at God's richt han'.

388. *Balmaghie.*—It is accounted unlucky to harry a robin's nest.

The Lark.

389. *Balmaghie.*—'Geed the laverack's heicht, I cudna follow.'

The Peewit.

390. *Kirkmaiden.*—The Peeweet is called Tappitie-wheet.
391. *Balmaghie.*—

Peeweet, peeweet,
I built my nest in a coo's fit,
An I rue it, I rue it.

The Cuckoo.

392. *Dalry.*—The first time of the season one hears a cuckoo, the number of times the bird utters its note indicates the number of years till marriage or death, according as the one that hears may be married or unmarried.

393. It is unlucky to hear the cuckoo for the first time of the season when one is in bed or before breakfast.

394. *Borgue.*—It is unlucky to shoot a cuckoo.

395. *Corsock.*—The first time one hears the note of the cuckoo, let her or him turn three times round, and below the foot will be found a hair of the colour of the hair of the future husband or wife.

The Rook.

396. *Mochrum.*—It is regarded as lucky to see crows (rooks) about the dwelling-house.

397. When crows fly low, rain is not far off.

398. *Dalry.*—It is unlucky to destroy a rookery.

399. *Borgue.*—In days gone by it was accounted unlucky to shoot crows.

400. *Rerrick.*—Rooks 'diving,' *i.e.*, flying up and down and wheeling, is an indication of a breeze.

The Magpie.

401. *Kirkmaiden.*—The magpie is regarded as a bird of ill omen.

402. *Mochrum, Dalry.*—It is unlucky to see a single magpie.

403. *Minnigaff.*—It is considered unlucky to see a single magpie when one is going a journey.

404. *Borgue.*—The appearance of three magpies near a dwelling-house is an indication that a funeral will soon go from that house.

405. *Minnigaff.*—It is accounted unlucky to shoot a magpie. My informant's father would on no account shoot one.

406. *Kirkmaiden.*—

Yin's sorrow,
Twa's mirth,
Three's a beerial,
Fowr's a birth.

407. *Minnigaff.*—

Yin's sorrow,
Twa's mirth,
Three's a funeral,
Fowr's a birth,
Five's a ship on the sea,
or,
Five's a message from over the sea,
Six is a letter coming to me.

408. *Kells.*—

Yin's sorrow,
Twa's mirth,
Three's a beerial,
Fowr's a birth,
Five's rain,
Seven's frost,
The worst o' a'.

409. *Forfar.*—

Ane's sorrow,
Twa's mirth,
Three's a weddan,
Fowr's a birth,
Five's a cirs'nan.
Six is hell
Saiven's the deevil himsel'.

410. *Ayrshire.*—The formula regarding the magpie when seen by a woman great with child is:—

Yin's joy,
Tway's grief,
Three's a girl,
Fowr's a boy.

411. *Minnigaff.*—When one sees a magpie the words: 'Sorrow to you and none to me' are called out.

412. *Balmaghie.*—

Yin's sorrow,
Twa's mirth,
Three's a beerial,
Fowr's a birth,
Five's a waddin',
Six is a ship sailin'.

413. *Rerrick.*—

Yin's sorrow,
Twa's mirth,
Three's a funeral,
Fowr's a birth,
Five's a shipwreck,
Six is a waddin,
Seven's a death.

Peacock.

414. *Corsock.*—It is unlucky to have peacock's feathers in the house.

The Adder.

415. *Kirkmaiden.*—If one meets with an adder and tries to kill it, but fails to do so by its escaping, a 'tryst' is made to meet with it next day at a fixed hour and place, and it will keep the 'tryst,' so that another opportunity is given to put it to death. The uncle of one of my informants actually did this. It was a common thing to do this when one of my informants was a boy.

416. A farmer of the name of Milnmine occupied the farm of Myroch. One day he went to an uncultivated hillock that was covered with whins to cut some. Near it was a hollow, and looking down into it from the hillock, he saw a great number of adders—as many as would fill 'the box of a cart—all squirming through each other,' with a white one in the middle of them. He threw among them the axe with which he was to cut the whins, and turned and fled. Next day he returned to search for his axe. In his search he found an adder-stone—a white stone with a hole through the centre of it. He preserved it carefully by putting it into his 'kist.' He was never without money afterwards.

417. *Minnigaff.*—My informant's husband had an adder-stone. It was a small round stone with a hole in the centre.

418. *Kirkmaiden.*—If a fire is kept burning for seven years continuously, a serpent issues from it.

419. *Corsock.*—A cure for the sting of an adder is for the one stung to drink new milk to vomiting.

420. A cure is to drink new milk and to rub the wound with a salve made by boiling ash leaves with new milk.

421. *Borgue.*—A decoction of ash leaves boiled in milk is applied to the wound caused by the bite of an adder. My informant saw this applied to the cure of a calf stung by an adder about 1850.

The Wasp.

422. *Rerrick.*—It is the belief that wasps do not sting during the month of September.

The Black Snail.

423. *Dalry.*—In going on a journey if you meet a black snail, take it by the horns, throw it over the right shoulder without looking behind, and money will be got before the journey is finished.

Caterpillar.

424. *Girthon.*—The caterpillar of the Nettle Butterfly (*Vanessa urticæ*) bears the name of 'Grannie.' When one meets one crossing the path or otherwhere, it is spit upon. If this is not done, it is believed that some misfortune will befall the grandmother, if she is alive.

The Spider.

425. *Balmaghie.*—It is accounted unlucky to kill a spider.

Trees and Shrubs.

426. *Borgue.*—The Boortree, *i.e.*, the elder, used to be planted round kailyards and near dwelling-houses as a protection against witches.

427. *Kirkmaiden.*—There are old-fashioned folk that will not allow a domestic animal to be struck with a 'boortree' stick.

428. *Corsock, Kirkmaiden, Balmaghie.*—A branch or piece of rowan tree used to be placed over the byre-door inside to keep off witches.

429. *Kirkmaiden.*—My informant has seen pieces of rowan tree laid on the mantel-piece to protect the house from witches.

430. *Portlogan.*—The thowl pins of a boat, or at least some of them, are always made of rowan tree.

431. *Kirkmaiden.*—Fishermen tie their lines to a rowan stick to keep the witches at a distance.

432. *Borgue.*—Rowan tree was used as a protection for unbaptized children against witches.

433. *Balmaghie.*—Our Saviour always carried in one hand a staff of holland, *i.e.*, the holly tree, and in the other a rod of rowan tree.

434. *Corsock.*—The farmer of Grogo Mill had in the byres some of the stakes to which the cattle are fastened, made of rowan tree, as a safeguard from witches. He died about ten years ago.

435. *Rerrick.*—My informant saw an old woman bring a piece of rowan tree into the byre of one of her neighbours on the occasion of a cow falling ill.

436. *Balmaghie.*—About twenty years ago my informant saw at Lochinbreck a woman milking her cow tied to a rowan tree.

437. *Corsock, Kells.*—In houses built some time ago, it was quite common to have some of the lintels made of rowan tree.

438. *Corsock.*—It was customary to plant rowan tree in the garden.

438*a*. *Kells.*—It was a custom to plant rowan tree as well as elder, near the dwelling-house and byres, as a protection against witches.

439. *Corsock.*—'Binnans,' *i.e.*, bindings for cattle, were formerly made of bent rods of wood. It was not uncommon to have some of them in each byre made of rowan wood as a safeguard against witches.

440. *Kirkmaiden.*—In Claish Glen, near Portlogan, grow fairy trees, *i.e.*, blackthorn bushes, which no one will cut, and some will not even touch them.

441. A blackthorn bush growing in a field is sometimes called a 'fairy thorn.' It is not removed, though it stands in the way.

442. *Dundrennan.*— Many haws
Many snaws.

Haws are in most abundant profusion this season, and my informant

has often heard the saw repeated within the last months (September 1896).

443. *Kells.*—A puppy poisoned by eating a skin that was being prepared with arsenical ointment, salt dissolved in warm water was at once poured over its throat. A decoction of ash leaves boiled in milk was afterwards administered. The dog recovered. (Told by the gamekeeper who did so. *Cf. No.* 421.)

Diseases.

Whooping-cough.

444. *Kirkpatrick, Durham.*—My informant has talked with a woman whose maiden name was the same as that of her husband's, who used to give a 'piece' to children labouring under whooping-cough that were brought to her for cure.

445. *Kells.*—My informant has seen children labouring under whooping-cough brought to receive a 'piece' from his wife, whose maiden name was the same as his own. When the child was unable to eat the whole of the 'piece' that had been given, the remainder was carefully wrapped in the child's pinafore and taken home.

446. *Rerrick.*—A cure for whooping-cough is to put the patient through under the belly of an ass.

447. *Corsock.*—It was a custom to take children having whooping-cough away in carts four or five miles to the hills, to cure them of the disease.

Warts.

448. *Corsock.*—Put ivy leaves steeped in vinegar over warts as a cure. My informant has tried this cure.

449. A cure for warts is to rub them with green bean-leaves. My informant has done this.

450. The juice of Dandelion (*Leontodon taraxacum*) is used as a cure for warts.

451. Swine's blood rubbed over warts dispels them.

452. *Kells.*—Take a potato, make a hole in it, fill the hole with salt, and allow it to melt. Rub the warts with the lotion.

453. *Crossmichael.*—Take a pebble for each wart, roll them in a piece of paper, and lay the parcel on a public road. Whoever picks up the parcels gets the warts.

Whitlow.

454. *Corsock.*—Kill a fowl, rip it up, and tie it round the affected finger or thumb.

The Mumps.

455. *Corsock.*—The Mumps (?) is called 'Branks.' The mode of cure is to put a horse's branks over the patient's head and lead him or her to water as one does a horse.

Jaundice.

456. *Balmaghie.*—Strip off the inner bark or fell from the wych elm, boil it, and drink the juice. There is one of these trees about a quarter of a mile from Laurieston. It is quite a practice for folks to come to it for a few branches to get the bark. Sometimes they come from a distance,

as it is the only tree of the kind in the district. It has been cut down oftener than once, but new shoots have sprung up.

The Hair.

457. *Portlogan.*—If one's hair when cut is burned, it will make him 'that cross that there is nae leevan in the hoose wi' 'im.'

458. When one's hair is cut, it is carefully gathered up, twisted together, and pushed into the thatch of the dwelling-house.

459. *Kirkmaiden.*—When one's hair is cut, it is gathered up, put into a hole of a dyke, so that the birds may not get it.

460. *Portlogan.*—If birds get one's hair and build their nests with it, the late owner of it will have headache as long as the female bird remains 'clocking.'

Birth.

461. *Kirkmaiden.*—The Bible was put below the pillow of a woman in travail. (Informant eighty-one years of age.)

462. *Minnigaff.*—After the birth of a baby there is a feast called 'The Blythe Meat.' A kebback always forms part of the good things. The father cut a big piece off it, put it on a plate along with a knife, and handed it to the mother in bed. She cut the cheese into small pieces and gave each of the guests a piece.

463. *Kirkmaiden.*—At 'The Blythe Meat' there is always a kebback or cheese, called 'the cryin-out cheese.' The father always cuts it. The first piece cut was always given to the nurse. It was larger than the pieces given to the others present at the feast. (Informant eighty-one years of age.)

464. *Kirkmaiden.*—It was the custom for the mother to fetch water from the well for the first time after her confinement in a very small vessel, most commonly in her thimble. This was done to keep the baby from 'sliveran.' My informant (eighty-one years of age) was told to do this.

465. *Kirkmaiden.*—It is unlucky to put the first-born child into a new cradle. (Informant eighty-one years of age.)

466. A cradle, when taken into a house, is not taken in empty. (Informant eighty-one years of age.)

467. *Balmaghie.*—A cradle is always taken into a house with its foot foremost.

468. When a cradle is borrowed, something is always put into it.

469. *Kirkmaiden.*—The cradle is rocked across the floor with its head towards the door. (Informant eighty-one years of age.)

470. *Laurieston.*—The cradle is always placed across the floor.

471. *Kirkmaiden.*—A Bible was usually put into the cradle till the child was baptized.

472. *Dalry.*—Sometimes a piece of bread and cheese is tied under the baby's dress when about to be baptized. After baptism the bread and cheese are given to the unmarried present at the baptism, who put them under their pillows to 'dream on.'

473. *Kirkmaiden.*—On the occasion of a baptism, when the minister left the house, sometimes an elderly woman would sprinkle part of the baptismal water over the other children of the family, and ask God to bless them. This custom is sometimes followed at the present time.

474. *Kirkmaiden.*—The one that saw a baby's first tooth had to make the present of a dress. (Informant eighty-one years of age.)

Marriage Divination.

475. *Kirkmaiden* (1).—Two stalks of a plant beginning to flower, but without bloom, are taken, one to represent the 'lad' and the other the 'lass,' and laid beside each other under a stone. Next morning the diviner makes an examination of the stalks. If both stalks are in bloom, the love will be mutual; but if only one is in bloom, all the love is on the side of the one whose stalk is in bloom.

476. (2) The first egg of a 'yearack,' *i.e.*, a hen that begins to lay the year she is hatched, is taken and broken, and the white of it is dropped into a glass filled with water. From the forms made by the white of the egg in the water omens of coming events are drawn.

477. (3) Take a snail on the morning of May Day and shut it up in any kind of dish. Omens are drawn from the figures made by the slime. The diviners tried to detect the form of letters in the slime marks.

478. *Portlogan* (4).—The young woman that divines takes a mirror and stands with her back to the moon, and holds up the mirror to the moon so as to let the moon strike on it. As many images of the moon as are reflected in it, so many years will pass before she is married.

479. *Minnigaff.*—If a young unmarried woman eats on Hallowe'en a whole herring, *i.e.*, with scales, bones, entrails, and fins, without speaking a word, and then goes to bed also without speaking, she will see in a dream the man that is to be her husband. My informant has known of this being done.

480. If an unmarried woman on Hallowe'en goes through the barn, entering by the one door and going out by the other, with a stocking on the wires, she will 'meet her fate,' *i.e.*, she will meet her future husband. My informant knew a young woman who did so. Her master met her. The young woman thought some one had sent him. She went to the dwelling-house and told her mistress, who was lying very ill. All that the mistress said was: 'Mary, be kind to my wee ones.' She died next day. In course of time Mary was married to her master.

481. *Ayrshire.*—The first time a young woman sees the new moon she takes her garter and begins to cast knots on it, and without stopping to keep in mind the number of them, she repeats this formula:—

This knot I knit
To see the thing I ne'er saw yet,
To see my love in his array
As he walketh every day.
If that he appears in green,
Better his face I ne'er had seen;
If that he appears in blue,
His love is ever true.

If at the end of repeating the formula nine knots have been cast, the wooing will end in wedlock; but if not, the wooing will end in failure.

482. *Balmaghie.*—If an unmarried man or woman is asked to take the last piece of food on the dish, it is an indication of getting a handsome wife or husband.

483. It is accounted unlucky to hear one's own proclamation of banns of marriage made in church.

484. *Mochrum.*—It is unlucky to have the bridal dress fitted on.

485. *Dalry.*—It is not lucky for a bride to put on the bridal dress before the marriage day.

486. *Mochrum.*—A bride ought on no account to look in a looking-glass after being dressed.

487. *Dalry.*—If the bridegroom enters the marriage-house before the minister, the married pair will not live together.

488. *Kirkmaiden, Mochrum.*—The minister must always be in the bridal house before the bridegroom enters. If this is not the case the bridegroom and his party wait till the minister enters. I have seen this.

489. *Mochrum.*—It is considered unlucky if the minister shakes hands with the bride or bridegroom before they are joined in marriage.

490. A mother should not see her daughter married.

491. It is accounted unlucky if the bride-cake is broken or chipped.

492. It is unlucky to be married to a bride who is with child at the time of marriage.

493. *Laurieston.*—It is accounted unlucky for a marriage party to meet a funeral. A farmer with his party was driving to be married. A funeral was seen approaching along a road that joined the road leading to the church and churchyard. The marriage party drove quite quickly so as to get in front of the funeral procession, but did not make out to do so. The bridegroom took the matter much to heart. After marriage, things did not go well on the farm. This misfortune, as well as every mishap that befell, was attributed to the funeral *cortège* meeting the marriage party. The farmer brooded so much on the matter, and spoke so constantly on it, that his wife's life was made miserable. My informant knew the farmer.

494. *Rerrick.*—It is accounted unlucky for the bride and bridegroom to meet during the time between the proclamation of banns and the meeting before the minister to be joined in marriage. In the parish of Rerrick a marriage took place between a pair that lived in the same house. On the afternoon of the Sunday on which the proclamation of banns was made, the bride and bridegroom took a walk together along the sea-shore. This act excited no small attention, and called forth many remarks about how improper it was to do such a thing.

495. *Crossmichael.*—It is unlucky to finish a bridal dress and then put it on to see how it fits or looks. Some little bit, such as sewing on a hook or button, is left unfinished. After trying on the dress it is finished. This was done in the case of my informant's daughter on the occasion of her marriage in August 1896.

496. It is considered lucky if the dressmaker accidentally let slip from her hand the bridal dress she is making. My informant's daughter was married in August 1896, when the dressmaker who lived in the house of the bride's father to prepare the bride's outfit told this 'fret.'

Marriage Customs.

497. *Kirkmaiden.*—In the days when hand-spinning was part of the employment of the women of the household, the young women spun the thread and yarn for their own sheets and blankets.

498. The bride's mother sometimes went to invite her guests to the marriage. The bridegroom invited his own guests.

499. *Minnigaff.*—At the feet-washing, the feet, both of the bride

and bridegroom, were put into the bine [hooped tub (*cf.* bin)] at once. The water was mixed with cinders and soot.

500. *Mochrum, Dalry.*—A bride must always wear something borrowed.

501. *Kirkmaiden.*—An oatmeal cake used to be thrown at the bride's head as she was entering her future home. It was accounted lucky if it struck her and broke.

502. *Dalry.*—My informant has seen a farle of oatmeal cake broken on the bride's head as she entered the door of her own house.

503. *Ayrshire.*—When the bride came to the door of her new home, an oatmeal cake was thrown over her head. It was accounted lucky if it broke in falling, or when it fell on the ground.

504. *Crossmichael, Kirkmaiden.*—The bridegroom's mother, if alive, often was the one to give the bride the welcome to her own house.

505. *Laurieston.*—In villages, as the bridal procession is passing, the children have a custom of calling out 'Ba! Ba!' Coppers are thrown among them. When the bridegroom's party is approaching, the bride's party at times rushes out and meets it. Both parties meet each other with much shouting.

506. *Balmaclellan.*—It was not long ago the custom, when the bridegroom's party was within a mile or so of the abode of the bride, for a few of the young men to set out to 'run the broose.' The bride gave a silk handkerchief to the one that reached the house first, and so 'won the broose.'

507. *Laurieston.*—The mother is never present at the marriage of any of her children.

507*a*. *Crossmichael.*—The minister commonly cuts the bride-cake. In doing so he hands the 'toorack'—*i.e.*, the top, to the bride. The part below is given to the bridegroom, and the remainder is cut up for the guests. This custom was followed at the marriage of my informant's daughter in August 1896.

508. The door is thrown wide open when the bride is entering her new home.

509. Old folks have told my informant that it was at one time the custom, when the bride presented herself at the door of her future home, for one to take a besom and to sweep the floor of the apartment; the bride entered towards the sweeper (?), all the time repeating the words—

'Soop the hoose till the bride comes in,'

till the bride reached the hearth.

510. *Balmaclellan.*—Sometimes it was an aged woman who welcomed the bride to her own home. She broke bread over her head. This bread was taken by the unmarried folks and placed below their pillows 'to dream on.'

511. *Crossmichael.*—When the bride entered her own house it was the custom at times to go right up to the hearth and touch the 'crook.'

Death Omens.

512. *Corsock, Borgue.*—A dog howling at night is a portent of death.

513. *Kirkmaiden.*—Some years ago one of the gamekeepers at Logan House took ill, lingered for some time, and died. For a good many days before his death the dogs kept up a great howling, generally in the gloam-

ing. A day or two before the death took place, one dog in particular gave way to extraordinary howling. It all ceased after the death.

514. *Balmaghie.*—Chairs cracking in a house is a portent of death in the family.

515. *Dalry.*—Doctor Trottar was one day called to visit a patient. When setting out, the horse stumbled and fell. Those who saw what took place said the patient would die. The patient died. (Told by his daughter.)

516. *Kirkmaiden.*—My informant's grandfather, a carpenter, said he always heard the noise of a saw during the night before he got the order to make a coffin.

517. My informant's father, a carpenter, said he always heard one knock on the end of his own bedstead before he got an order to make a coffin.

518. *Kells.*—If one dies, and lies unburied over Sunday in a parish, another will die within the week.

519. *Rerrick.*—A dog howling at night is an omen of death. A young woman at a farm in Rerrick was seized with inflammation of the lungs. After she fell ill, the dog began to howl, and no means could be found to stop the animal while she was lying ill. She died, and after the death the dog ceased his howling.

520. My informant at Burnfoot was one afternoon entertaining a friend or two at tea. As they were making ready to leave three extraordinary knocks were heard in a room on the other side of the lobby. The guests and she immediately went into the room to try to find out the cause of the knocks. One of the guests searched all round and under the table from which the knocks seemed to proceed. Nothing could be seen. A post or two after brought intelligence of the death of a very intimate friend, who had died about the time the knocks had been heard.

521. A man named James Whyte died at Burnfoot. On his death his son went to the house of my informant's father, tapped on the window, and said his father had just died. Immediately before the news of the death was given, a very loud crash, as if something had fallen and been smashed to pieces, was heard in one of the rooms.

522. My informant's grandmother told her that when a child of hers, twenty-one months, was lying ill in the cradle, a most sweet sound was heard to begin near the door of the apartment in which the cradle stood, and move round the apartment, past the fireplace, to the cradle, where it stopped. When the mother looked into the cradle, the child was dead.

523. *Balmaclellan.*—When one of the ministers of Balmaclellan was lying very ill and low, his niece was one night watching him. All at once the sweetest music she had ever heard began. Her uncle heard it too, and said: 'That's a call for me. I will not be long here.' He died not long after. (Told by the minister's niece to my informant.)

524. *Laurieston.*—If a dead body lies unburied over Sunday, there will be 'other tway deaths within the week,' or if not within the week within a short time.

Death Customs.

525. *Kirkmaiden.*—All the doors and windows of the house in which one lay dying used to be thrown open. My informant has seen her sister do so.

526. *Portlogan.*—When one was dying, it was the custom to keep the door of the house wide open.

527. *Kirkmaiden.*—It is the custom to stop the clock when one dies. My informant has seen this done within three years.

528. When the eyes of a dead person do not close, penny pieces are put over them.

529. *Balmaghie.*—To 'strauch a corpse' is to lay out a dead body.

530. *Kirkmaiden.*—The dead body always lies on the bed on which the death takes place, till it is dressed and put into the coffin.

531. It was not an unusual thing for a woman to spin the thread of her own grave-clothes.

532. My informant, a carpenter, is in the habit of washing his hands after putting the dead body into the coffin. It was at one time the usual custom to do so.

533. A plate containing a little salt was till lately placed on the breast of the dead body.

534. The dead body, except for some special reason, is usually kept unburied for five or six days.

535. Till about twenty years ago it was the usual custom that a few neighbours, both men and women, met at the house of death about 10 o'clock at night. Refreshments were usually served as they arrived, and when they left in the morning. For these refreshments some brewed their own beer. A good deal of time was spent in reading the Bible, in singing psalms, with prayer occasionally.

536. *Balmaghie.*—One ought never to refuse to 'see a boddie's dead' when asked to look on a dead body.

537. *Mochrum.*—Invitations to a funeral used to be given till within a few years ago by a messenger. A common form of invitation was :—'Your company is requested to the funeral of at o'clock.

538. *Kirkmaiden.*—The messenger that called the people to a funeral almost never entered the house of those invited, but stood outside the door and gave the message. If he did enter the house, he did not sit down. On finishing his round, he returned to the house of death.

539. Refreshments till within a few years ago were given to those that attended a funeral. In the case of a farmer or any of his family the guests assembled in the barn. Men were appointed to hand round the refreshments, and they were called 'service men.' There are generally four or five, and at times as many as six 'services.' Commonly a 'service man' stood at the door and proffered a glass of whisky to each one on his arrival. When all were assembled, the 'service men' began their work. First came a 'service' of whisky with bread and cheese—'funeral bread,' *i.e.*, oaten cakes baked for the funeral. The second consisted of sherry and port wine with short-bread, or small 'bakes,' *i.e.*, biscuits, or 'dollar biscuits.' The third might be of rum or brandy, and the fourth of gin, or whisky, or beer.

When the custom fell into disuse, many of the old-fashioned folk expressed their displeasure, and said that 'a beerial was na worth going to.'

540. *Mochrum.*—At a funeral sometimes whisky and a bake were given at the church door.

541. *Kirkmaiden.*—After the funeral, some of the relatives, a few friends and near neighbours, with the one that had invited the people to

the funeral, return to the house of the departed and partake of a meal, commonly 'high tea.' The joiner who makes the coffin commonly gets a list of those that are wished to be so entertained.

542. *Kirkmaiden, Minnigaff.*—It was till not long ago a custom to cut off a piece of the grave-clothes immediately before the coffin was closed, and to preserve it.

543. *Kirkmaiden.*—The coffin is taken out by the door and not by a window, except in rare cases when it cannot be taken through the doorway. The body must be taken out by the door the deceased came in.

544. *Balmaghie.*—At a funeral the women of the house never go outside, but shut themselves up.

545. *Kirkmaiden.*—The coffin is usually carried to the graveyard. To take the coffin to the graveyard in a cart, which is sometimes done, is accounted a less honourable mode of burial than to be carried.

546. Fifty years ago there was very little conversation carried on by those that formed the funeral procession; and if any was carried on, it was in subdued tones. It is quite different nowadays. There is conversation, and it runs on all kinds of subjects.

547. *Mochrum.*—In tolling the church-bell at a funeral, three tolls in succession are given, and then an interval.

548. My informant, a gravedigger, has sometimes seen each of the relatives of the deceased throw a handful of mould on the coffin after it was lowered into the grave.

549. *Kirkmaiden.*—A man of somewhat bad character died at Logan. When the coffin was being carried to the grave many extraordinary difficulties came in the way. At last one old man called out, 'In God's name, lay 'im doon, an' lat the deil tack 'im.'

550. *Crossmichael.*—When one dies the room is darkened.

551. When one dies the clock is stopped. My informant has heard the order given 'Stop the clock.'

552. On the occasion of a death it is the custom to burn the chaff of the bed and the bed-straw.

553. *Balmaclellan.*—Between forty and fifty years ago, Fanny Ireland or Macmillan, an old woman that lived in Balmaclellan, fell ill. The aunt of my informant's wife went to ask how she was. She found she had not long to live. She stayed a long time. When she returned home, her mother asked her why she had stayed so long. She said she had been helping to carry the dying woman 'weathershins' round her house, and 'was jist worn oot' doing so. The women had taken the dying woman from bed and carried her 'weathershins' round the house 'to keep awa' evil spirits.'

554. *Mochrum.*—Unbaptized children used to be buried under the wall of the graveyard or of the church. My informant has done this.

555. The church bell was rung at the funerals of children that had been baptized, but not at those that had not been baptized.

556. *Kirkmaiden.*—Still-born as well as unbaptized children are, or were till lately, buried in the gloaming and under the walls of the church. It is unlucky to step over the graves of such.

Suicides.

557. *Corsock.*—The ridge of the Lowther or Lead Hills, along which runs the boundary between the counties of Lanark and Dumfries, was

a common place where the bodies of suicides were buried. (Told in Corsock.)

558. *Kirkpatrick-Durham.*—A woman in this parish, not very many years ago, committed suicide. Her body was buried in the churchyard. During the night after the funeral, the coffin was dug up and placed outside, against the door of the house in which she had lived. The sheriff made his appearance to settle the matter. The coffin was interred outside the churchyard wall, near the gate, just off the public road.

559. *Kirkmaiden.*—The body of a suicide was buried close under the wall of the churchyard, outside. Sometimes the wall was taken down to allow the coffin to be placed below the wall. When the grave was filled, the wall was rebuilt.

560. *Mochrum.*—If there was a tree in the churchyard, the body of a suicide was buried under it.

561. *Dalry.*—A suicide at Knockman was being carried to the graveyard at Dalry. After the procession had gone about a mile, a crow alighted on the coffin. Those that were carrying the coffin set out to run as fast as they could. They could neither stop nor let go their hold of the bier and give it to others. The race continued as long as the crow sat on the coffin. At the village of Dalry the crow flew off, and the procession went on at leisure to the churchyard. This took place about a hundred years ago.

562. *Kirkmaiden.*—In one case the mother of a suicide went to America. The body of her son had been, according to custom, buried outside the wall of the churchyard. The churchyard was afterwards enlarged, and the suicide's grave came within the walls. The mother came to know the fact, and in writing home to a friend said how thankful she was that her son's grave was now within the walls of the churchyard.

The Drowned.

563. *Balmaghie.*—It is accounted unlucky for the one that is the first to touch the body of one that has been drowned or has perished.

564. *Dalry.*—After a time a light appears over the spot where the body of one that has been drowned lies.

565. *Balmaghie.*—A blue light appears over the spot where the body of one that has been drowned lies on the ninth day after death, when the gall-bladder breaks.

566. *Kirkmaiden.*—The one that saves another from drowning runs the risk of being drowned.

567. *Newton Stewart.*—My informant, an ex-policeman, in his investigation into a case of drowning in the river Cree, heard old people say, 'She has not got her complement yet.'

568. My informant, an ex-policeman, saw in 1889 a loaf hollowed out and a little mercury put into the hole. The loaf was then laid into the river Cree, at the point where the young man that had been drowned fell into the water, and allowed to float down.

Other Superstitions relating to Death.

569. *Kirkmaiden.*—A grave is not opened till seven years after the last interment.

570. *Rerrick.*—It is believed that if the windows of the room in which a dead body lies are opened, the decay of the body is hastened.

571. *Balmaghie.*—It is accounted unlucky to meet a funeral.

572. It is looked on as unlucky to stand on the threshold and look on a passing funeral.

573. *Kirkmaiden.*—When the master of the house dies, if bees are kept, they die or leave. My informant said he knew of such cases in the parish.

Farming Customs.

Sowing.

574. *Kirkmaiden.*—When once the bags containing the seed-grain are taken to the field to be sown, if rain come so as to prevent the sowing from being carried out, they are not lifted from the field and carted back to the barn, but left till the weather permits the seed to be sown.

575. The grain used to be sown from a sheet knotted up and hung from the neck. This sheet had always to be taken clean out of the fold for the grain that was first sown.

576. If the knot by which the sheet from which the seed-grain was sown was tied undid itself, the sower would not live to sow another spring. W. Morrison, farmer in East Muntlock, was sowing one spring when the knot of the sheet unloosed itself. He died before the next spring.

Reaping.

577. *Galloway* (general).—Reaping was at one time done by the hook.

578. *Rerrick.*—The reaper on the first 'rig,' who was always supposed to be the best workman, was called 'The Pintsman' (pointsman), and the one on the last 'rig' 'The Heel.' There was a binder and stooker to each four 'shearers.' Breakfast was between five and six o'clock in the morning, and consisted of oatmeal porridge and milk. The porridge was always made the night before in a big boiler, and poured into small wooden tubs called 'gones.' These 'gones' were then covered up with the grain sack, to keep the porridge warm. The steam got condensed, and fell down all round the inside of the 'gones,' making the outside of the porridge cold and unpalatable; so that, as my informant said, 'We suppit as fast as we cud, till we got to quhaur they were warm.' For sixteen reapers and four binders there might be three of these 'gones.' They were placed along a big table. A basin to hold milk was placed for each two, and not one basin for each.

Instead of milk what is called 'crap' was sometimes used. This 'crap' is boiled whey. When curd for making cheese is separated from the whey, small lumps of curds are left in the whey. When all the curd that can be got is separated from the whey, the whey is boiled. This boiling causes all the small particles of curd to coagulate still further, and then to float. When the whey cools, they sink to the bottom.

Dinner, which consisted of broth made of swine-flesh along with potatoes, was served at noon. Work was resumed almost as soon as dinner was finished, and was carried on without stop till 8 or 8.15, if daylight permitted. Supper consisted of porridge and milk, the same as breakfast. This was the course followed about fifty years ago on the farm of Baligue, parish of Rerrick. (Told by one that did harvest work on the farm for one harvest.)

579. *Balmaghie.*—The 'pint' (point) rig was shorn by the 'first man' in the kitchen, and the second rig by the byre-woman.

580. *Kirkmaiden.*—The one that cut 'the Hare' at times got five shillings.

581. Whisky was given to all the workers when 'the Hare' was cut.

582. 'The Hare' was commonly placed over the kitchen door.

583. 'The Hare' was often kept over the 'door-head' till the following harvest. (Informant eighty-one years of age.)

584. *Portlogan.*—'The Hare' was kept by some as long as it would hang together.

585. *Kirkmaiden.*—When 'the Hare' was cut, no more work was done that day.

586. About forty years ago, some had the custom of hanging up 'the Maiden' in the best room of the house.

587. *Balmaghie, Girthon, Kells, Dalry, Corsock.*—'The Hare' is called 'the Kirn.'

588. *Balmaghie.*—'The Kirn' was placed over the kitchen door, and the Christian name of the first man that entered would be the name of the husband of the byre-woman, and the Christian name of the first woman that entered would be that of the wife of the 'pint rig man.'

589. *Dalry.*—A fancy 'Kirn' was made, decked up, fixed to the wall of one of the apartments, and kept till the following year.

590. *Kells.*—In cutting the 'Kirn,' it was the aim of the reapers to cut it below the plaiting of the ears of grain. The one that cut it carried it home.

591. *Corsock.*—When scythes came into use, the 'Kirn' was cut by the reaper blindfolded. The quantity of grain left for it was divided into three, plaited, and the ears twisted together. The one that was to cut it was blindfolded, and led to a distance from it. He then set out to find it and cut it.

592. *Laurieston.*—A small quantity of grain was left for the 'Kirn.' Each reaper got a chance of cutting it. Blindfolded, he or she was led some distance from it, and then sickle in hand proceeded to find it out and cut it. When it was cut, a cheer was commonly raised. It was carried home.

593. *Kirkmaiden, Balmaghie, Kells, Kirkmaiden.*—There is a feast after harvest, which is called 'the Kirn.'

594. *Balmaghie, Kirkmaiden.*—'The Kirn' is sometimes given after all the crop has been secured in the stackyard.

595. *Kirkmaiden.*—'The Kirn' is at times given when the crop is all cut.

596. *Laurieston.*—The sheaf last cut was finely plaited and twisted. A branch of rowan tree with the berries was generally tied into the middle of it as a protection against witches. This was laid on the table at the 'Kirn' feast. After the feast was finished, dancing was begun either in the barn or granary.

597. *Kirkmaiden.*—A dish at the 'Kirn' feast is 'beetlet praties' (mashed potatoes), which are always stirred in the form of the figure 8 in being made ready. Into this dish were put a ring, a thimble, and a button. The ring signified marriage. The one that got the ring 'slept on it' that night.

598. *Corsock.*—Dirty water of various kinds used to be thrown over the one that brought the last load of grain from the field into the stackyard. This custom at times led to rough action in retaliation against

the one that threw the water. My informants have seen this custom carried out.

599. *Kirkmaiden.*—Women and boys were always lurking about corners with pails of water to throw over the one that brought from the field the last load of grain into the stackyard.

600. If whisky had not been given to the reapers when 'the Hare' was cut, the one that took the last load of grain into the stackyard objected to the throwing of water on entering it.

Fishing and Bathing.

601. *Kirkmaiden.*—Fishermen in turning their boats always do so sunwise.

602. Fishermen account it unlucky to take a lythe (a species of cod) for the first fish into the boat.

603. Fishermen put a few white stones into their boats to secure luck.

604 *Mochrum.*—Bathing in the sea is done when the tide is ebbing. It is believed that, if there is any disease, the rising tide brings it in, and one bathing at that time may catch it.

Lead-miners' Customs and Superstitions at Minnigaff.

Omens.

605. Miners count it unlucky to meet a woman as 'first fit' when they set out to work in the mine.

606. Meeting one with black hair, whether man or woman, is accounted lucky.

607. Before an accident took place, noises of various kinds were heard. Sometimes the noises resembled the voices of men speaking, sometimes like the sound of the miners 'travellin' the laither,' *i e.*, going up and down the ladder, and sometimes knocks were heard on the 'lock.'

608. Certain among the miners were looked upon as carrying ill-luck with them. If such a one, when a lode of lead was found, made his appearance in the section, the lode gave out in a short time.

609. There was no whistling in the mine. J. Moffat, a miner, whistled one day. Not long after a stone fell on him and killed him.

610. It was believed that no metal would be got if there was any profane swearing. An oath or profane word of any kind was therefore seldom heard in the mine.

611. It was usual for the miners to sing to bring luck. They sang either songs, hymns, or psalms.

612. Some men were accounted more lucky than others in finding metal.

613. Some men would not work for months near a spot where one had been killed.

Customs.

614. In sinking a shaft, when ore was struck, a barrel of beer was given by the mine-owners. It was drunk on the spot.

615. Every time a 'bunch' of ore was come upon, a barrel of beer was consumed.

616. The mine was divided into sections, and these were divided by lot among the different companies that wrought in the mine. At the head of each company was a foreman called the 'bargain-tacker.' He

was responsible for the working of the section, and to him the wages of the company that wrought the section were paid in the gross. He paid each of his company his share.

617. The first time the 'bargain-tacker' received his pay after receiving a new section and after choosing his own company, he had to 'pay his fittan,' *i.e.*, treat the men of his company.

618. When a young man of a company got married, the men of his company 'stood treat,' and often made a present besides.

619. When a miner was buried the working of the mine was generally stopped. The master and all the miners attended the funeral.

620. There was a good deal of eating, and more drinking, at a miner's funeral. Hence arose the saying: 'A Mines funeral is as guid's a Mines waddin'.' ['Mines' is the local name for Blackcraig Mines.]

621. 'Short-bread' was commonly used as part of the entertainment at a miner's funeral. It was commonly baked by neighbours and presented by them.

622. Any frogs that might have been found in the mine were carefully tended. They were carried to a place of safety, and food was given them.

Mining Terms.

623. Back-end was the place where all the rubbish of the mine was cast.

Black Jack, sulphur.

Gump o' lead, a pocket of lead.

Vogg-hole, a hole that is full of water. The lead hangs all round it 'like paps.'

The lead mines are not now wrought.

My informant was a miner from boyhood.

Omens—Luck and Unluck.

624. *Dalry.*—It is unlucky to put a pair of shoes on a table.

625. It is unlucky to lay the tongs on a table.

626. *Mochrum.*—It is unlucky to break a looking-glass.

627. It is unlucky if a looking-glass falls and is broken.

628. *Kirkmaiden.*—It is unlucky to give fire out of the house.

629. *Dalry.*—It is unlucky to stumble when going upstairs.

630. In going a journey on horseback, if the horse stumbles in starting, there will be no luck in the journey.

631. In setting out on a journey, if the left foot is placed first, there will be luck.

632. Sneezing in the afternoon is accounted unlucky.

633. *Balmaghie.*—To spill salt is unlucky. To do away with the unluck, a little of the salt is thrown over the left shoulder.

634. At the Communion in the Church of Balmaghie, one very wet Sunday an old man laid his dripping head on the Communion Table. He left the impress of his head on the white cloth. He died within the year. Leaving the impress was looked upon as very unlucky.

635. *Dalry.*—Sneezing in the morning indicates luck.

636. In setting out on a journey, if one puts the right foot first, luck attends the journey.

637. If one puts on any piece of dress inside out, luck follows as long as the piece of dress is worn as put on.

638. *Balmaghie.*—If one puts on a piece of dress inside out, it must not be changed. Changing puts away the luck.

639. *Dalry.*—If one sees a wraith in the morning, it indicates long life. It is not a good omen to see one at night.

640. *Galloway* (general).—It is accounted lucky to have the toes webbed or partly webbed.

641. *Dalry.*—Certain persons are considered as having a 'lucky hand.' 'You have the lucky hand,' is the saying.

642. A film of carbon hanging from a bar of the grate foretokens the arrival of a stranger.

643. If the black films that appear on the bars of a grate fall off at once when blown, strangers will soon arrive. If they require two or three puffs, it will be two or three days before they make their appearance.

644. If the youngest or the eldest of a family sneezes before breakfast, a stranger will arrive during the course of the day.

645. If the right hand becomes itchy, it is an indication that money will be received in no long time. If it is the left hand that itches, money will be paid away.

646. If the left ear becomes hot, one is speaking evil of you; if the right ear, good things are being said of you.

647. *Crossmichael.*—If the 'girdle,' or a pot, or any cooking utensil that may be hung over the fire, slips in the 'crook,' a stranger will arrive.

Giants.

648. *Balmaghie.*—At Barstolick there lived three giants that were the terror of the whole neighbourhood, and no one was bold enough to meet and fight them. At last a man of the name of McGhee undertook to do battle against them. He fell upon them unawares at night, and succeeded in killing them. For this deed he got a grant of the lands of Waylard.

649. A giant and his wife lived in a cave now called the Giant's Cave at Aldequhat. One day the giant fell asleep in his cave whilst a big kettle of fish was cooking. A man that was fishing in the loch went into the cave, found the giant asleep and his wife away. He overturned the boiling kettle over the giant's face, and blinded him. He jumped up in his pain and tried to catch the author of his misery. It was in vain. He could not see him. He asked his name in hopes that he might in after times have an opportunity of exacting justice from him. 'I mysel' is my name,' was the answer. After chasing the man to no purpose he roared: 'A' burnt, a' burnt.' The roar was heard by his wife, and she called back: 'Quha did it? Quha did it?' He answered: 'I mysel' did it.' Her reply was: 'I thysel' can blaw thysel'.' The man, dreading the wife's return, meantime made his escape from the cave with all speed, mounted his horse and fled, as the wife was coming to the cave. When she found out what had taken place, she set out in pursuit of the man that had done the evil deed. It was a hard race, but she overtook him. She seized the horse by the tail. The man turned round in the saddle and struck out with his sword and cut off her arm, and so escaped.

650. *Dalry.*—There was once a giant sived in Carsphairn. A family in the parish incurred his ill-will. He resolved to take his revenge. He went to the top of a hill called Dundeuch, seized a big rock, and threw it on the house in which the family lived. It fell on the house, crushed it, and killed all in it. The stone has been taken and made into gateposts.

The Devil.

651. *Kells.*—There was a large rock near the Old Bridge over the Ken, between Carsphairn and Dalry. The devil, looking from a hill called Dundeuch at some distance from the river, resolved to destroy the bridge. He seized a huge rock, but fearing that he might overshoot the bridge if he threw it with the force of his whole hand, poised it on his little finger and threw it. He misjudged the weight of it, and it fell short. The rock has been very much broken up for building purposes. It is known as 'The Deil's Finger-stane.'

652. *Dalry.*—A funeral was proceeding to the churchyard of Dalry along the road between Dalry and Moniave. When the procession reached a certain 'straun,' *i.e.*, stream, a stranger joined. No sooner had he done so than the *cortège* 'set up speed' and ran with great haste to the churchyard. The stranger disappeared suddenly, no one knew where. He was the devil. The deceased had made a compact with the devil and sold himself to him, and was to be claimed at the spot the stranger joined the funeral procession. He came to the appointed spot to 'claim his own.' When he got his own he disappeared. Hence the stream got the name of the Bargain Straun. (Told in Corsock.)

653. *Kirkcowan.*—The farmer of Balaird, part of which lies on the river Bladenoch in the parish of Kirkcowan, had a field of hay on the banks of the 'burn.' He and his servants were busy amongst it when a violent torrent of rain fell, and the burn came down suddenly in great flood, so that it overflowed its banks, and was sweeping away quantities of the hay. Seeing the crop floating away in spite of all their exertions to secure it, the farmer lost all control of himself, and gathering together the forks and rakes, &c., they were using, threw them into the rushing water, and cried out: 'B' the Lord! if ye (the devil) tack the hey, tack a' wi' you.'

654. *Girthon.*—The farmer of Culreoch, which lies on the banks of the river Fleet in the parish of Girthon, was a 'twisty aul' carle.' One very windy day he was carrying a bundle of fodder to give to some of his cattle. He had to go round a corner particularly exposed to the force of the storm. The wind caught the bundle of fodder as he tried to round the corner, and he was driven back oftener than once. At last he planted down his foot with force, bent his body against the storm, and burst out: 'Na, nor yet yir faythe aither.'

Brownie.

655. *Borgue.*—The Brownie is looked upon as a helpful being. Food used to be set in convenient places for the brownies to eat during night.

656. *Dalry.*—At Borgue the aunt of my informant's father used to lay out food for the brownies during night. For this kindly act they did all sorts of heavy work, as threshing.

657. Brownies did during the night the work of those that treated them kindly. At Bogue, in the parish of Dalry, there is a well called Kitty Ramsay's Well. Beside this well those who wished to have their services placed food for them. They ate the food, drank the water of the well, and did the work of their benefactors.

Fairies.

658. *Kirkmaiden.*—Some were in the habit of placing a basin of meal or a bowl of water on the dresser for the use of the fairies during

night. This act of kindness kept them on good terms with the household and from interfering with the cows.

659. *Dalry.*—On Halloweven the fairies rode on cats at the Holme Glen, Dalry. On that night considerate housekeepers shut up their cats, to prevent them from being laid hold of by the fairies.

660. *Kirkcowan.*—A man had a cow and a goat which he pastured in his little field. In this field was a knoll, and it was the abode of some fairies. They took to riding on the goat round and round the knoll. The man was at last under the necessity of selling the goat, so fond had the fairies become of riding the animal. He bought another and placed it on the field in the thought that it would be free from the attention of the fairies. Some time after his wife asked to go and see how the new goat was faring. He saw the fairies riding 'time aboot' round the knoll on the goat's back. (Thirty two years ago.)

661. *Dalry.*—About seventy-five years ago there lived a woman at the Brough, in the parish of Kells, in an old house about a mile from New Galloway. In front of the house door there was a slab over the drain that carried off the house dirty water. One day a fairy woman, dressed in green, appeared to her and asked her to throw her slops not on the slab but a little further off. She made a promise to her that if she did so, she would never come to want. The woman did so. Some time after she fell ill. Every morning a quantity of new pins was found on a small table that stood beside the patient's bed. The pins were sold, and the price of them was sufficient for the support of the woman. Dr. Trottar of Dalry came into possession of one of them. From that time forth money matters prospered with him.

662. *Kirkmaiden.*—My informant told me that he has heard of the site of a byre being shifted, because it had been built over fairy dwellings, and thus the water of the byre dropped down into it, and caused annoyance to its inmates.

663. When the new house at Greenan was being founded, a woman appeared and asked the masons and others taking a hand in the work to change the site. She told them that the house on that site would be right over her dwelling, and in consequence much annoyance and inconvenience would be caused to her and her household.

664. My informant's father used to say that he has heard the fairies singing in Glenlee.

Witchcraft.

665. *Kirkpatrick-Durham.*—An old woman used to say to my informant, when a boy, that the witches were all abroad on Halloweven, and that they would seize him if he went out of the house after dark.

666. *Rerrick.*—Mrs. G—— of Dundrennan Cottage, Rerrick, had a garden and sold the potatoes reared in it. Mrs. W—— who was looked on as 'uncanny,' wanted from her some of a particular kind as seed. She went to the cottage to buy them. When she entered, the female servant was 'kirnin.' She asked Mrs. G—— to sell her a stone of this particular kind of potatoes. She was told she could not have them, as they were all sold. She appeared not to believe this, and as she was leaving the house she looked back at the 'kirn.' No butter was got from that churnful.

667. *Crossmichael.*—A witch that commonly went by the name of Nanny lived in Crossmichael parish. One day a neighbour's cow fell ill and fell down. Nanny was known to have a grudge against the owner,

and was suspected as the cause of the illness. Several of the folk around assembled to give what help they could, and among them was Nanny. They tried to lift the animal, but were unable to do so. The minister made his appearance. When he saw how things stood, he said : 'Nanny, you an' me 'ill try t' lift her.' Nanny made her excuse : 'Hoot awa', hoo cudd an aul' boddie like me help t' lift her?' 'We'll try 't,' said the minister. Nanny could no longer refuse. So the minister and Nanny laid their hands on the cow to lift her. The hands had hardly touched her, when up jumped the animal as if nothing had been the matter. Nanny had witched her.

668. *Rerrick.*—A woman named Mrs. Williamson lived on a point called The Scaur, in the parish of Colvend. Sailors and fishermen were always most attentive in making gifts to her. If she was neglected, some misfortune befell the ship or boat.

669. Mrs. W—— was one day nursing for a short time the child of a neighbour against whom she had a grudge. In dandling the child, 'she gave it a twist.' The child grew up hunchbacked.

670. *Corsock.*—A herd named McQueen was one day out with a gun to kill a hare. He put up one, fired, and struck her hard without killing her. He ran after her, and was again and again on the point of putting his foot on her, but she always got off. At last she disappeared. It was a witch in shape of a hare.

671. *Kells.*—Witches used to meet and hold orgies. A woman on one occasion was going to one of these, and to be able to contribute something to it she required some money. She churned her cream except a small quantity, sold the butter in Dalry and bought a bottle of whisky. To conceal from her husband what she was going to do, she took the small quantity of cream she did not put into the first churning, churned it, and showed the butter to her husband as if that was all the butter made.

672. *Kirkmaiden.*—My informant has seen a reputed witch and a descendant of one of the noted Galloway witches riding on a stone dyke.

673. *Dalry.*—My informant one day engaged Jennie Mainsie, a reputed witch, to cut some seed potatoes for her. She treated the woman well and paid her full wages. Before leaving she asked to be shown round the garden. This was done. She then requested to be allowed to look into the coal-house. Her request was granted. After all this she said, 'Noo, I've dune ye a' the ill I can.' Next morning my informant went into the coal-house to bring in coals for the fire. A big lump of coal fell on her foot and crushed it.

674. *Kirkmaiden.*—If one went to a witch's house, took a little straw from the thatch of it, and burned it, all power to harm the one that did this was taken from her.

675. *Laurieston.*—When a cow's milk was taken away by a witch, as much of the animal's milk as could be drawn from her was put into a pot with a quantity of pins. The pot was hung over the fire to boil, and the door of the house was bolted. The witch in due time came to the door and asked admission. Her request was denied. If she were admitted, the milk would not be restored, but if kept out the milk would return.

676. *Kirkmaiden.*—On the farm of Kilstay, tenanted by Mr. Kerr, a grass-witch at one time wrought evil among the cows, so that no butter could be got from the cream taken from their milk. A man that had wide fame for his skill in such cases was called from Ireland. The man came. The first step he took was to go into the byres and count the

animals, and to examine them. He then ordered all the wickets or holes in the walls of the byres to be opened, so that whatever of evil influence was in them might get out. He next ordered all the members of the household to go into the dwelling-house, shut the door, cover all the windows, fall on their knees, and pray to God that what he was going to do would have the effect he wished, and not stir or open the door till three knocks were heard on it. He went into the byre, and did something no one knew, but the bellowing of the animals was terrible to be heard. After a time the three knocks on the door were heard, and the door was opened. The man had accomplished his work. When the cows were examined, each had a piece of vervain tied into the hair of the tail. The man then made a rope of hair, and tied it threefold round the bottom of the churn, and at the same time gave orders that it should not be removed. Things now went on all right, so that it was at last deemed safe to remove the rope. This was done with the result that no butter was got as formerly. The rope was replaced and Mr. Kerr, who was a handy man, made a sort of shallow tub to put over it and preserve it. Butter was again got. Vervain stitched into a band of silk was after this worn round the waist next the skin by the folk of Kilstay Farm.

Evil Eye.

677. *Balmaghie.*—There once lived at the Waukmill, Balmaghie, a woman named Mrs. Melroy, who had the evil eye. The power was so strong that if when milking her cow, she had looked on the milk in the pail, it would have been sour before she reached the dwelling-house. Her husband was a dyer, and he would not allow her to look into the dye-vat, for if she did so the dye would not take.

678. *Dalry.*—If one carrying milk meets one with the evil eye, the milk becomes sour.

679. *Kirkmaiden.*—The fishermen of Dromore, when returning from gathering bait, do not care for one looking into the 'bait dish' on the bait.

Place Legends.

680. *Corsock.*—A diamond is believed to exist in Criffle Hill. Sailors see it glittering at night as they are sailing in the Firth. It cannot be found during the day, though search has been often made for it.

680*a*. *Kirkmaiden.*—There is a large boulder in a field on the farm of Aucabrick, parish of Kirkmaiden. The present tenant wished to remove it, and one day, without telling his father, went to remove it. He had gone so far with the work as to have a chain fixed round the stone and the horses attached to the chain. His father saw what was going on. He made all haste to the spot, and reached it in time to stop his son in his work. The stone is still standing in the field.

681. *Kells.*—In Carsphairn there is a place called Whanny Knowes, from the fact that there is a number of knowes or knolls all scattered about, popularly said to number 365. The rhyme is—

Every knowe
Would grass a yowe (ewe).

682. *Carsphairn.*—There is a narrow gorge in the river Deuch, parish of Carsphairn, a little above the Old Brig of Deuch, called 'The Tinker's

Loup.' This is one tradition of the origin of the name. A tinker that was passing along the road entered a house in which 'bleedy puddins' were being cooked for supper. No one was in the house. He seized the puddings and made his escape from the house. He was seen and pursued. He was on the point of being caught. To save himself he leapt the river at the spot that bears his name, and then sat down on the opposite side to rest and to enjoy his feast of 'bleedy puddins.'

683. *Corsock.*—There is an island in Loch Urr. A shepherd, accompanied by his dog, one day waded across the shallow part of the loch. Having reached the island, he laid himself down under some bushes as the day was warm. He began scratching the ground with his stick. He turned up a piece of turf, and under it he saw a pot of gold. He looked behind him, and near him stood a creature in shape of a man with eyes as 'big as a broth plate an' legs as thick as a corn sack.' He held a paper in his hand. He asked the shepherd to sign it, and said to him that the gold would be his if he did so. The dog in the meantime had taken to flight in complete terror. When the shepherd heard the terms of getting the gold, and noticed how the dog had behaved, he turned and ran. The dog in fright fled to the house, rushed below the bed, and would not leave his place of refuge for some days. Search was afterwards made for the treasure, but in vain. Another version of the tradition states that the shepherd dreamed that there was a pot of gold hidden on the island, and thus was led to search for it.

684. There is a well called the Lag Wine Well in the parish of Carsphairn. The tradition is that there is in it a lump of gold which is guarded by the devil. On one occasion some men resolved to lead away the water from the well to dry it so as to reach the gold. They met and began cutting a trench. They had not been long at work till the sky grew black as night, and a thunderstorm, accompanied with torrents of rain, burst over them. At the same time such swarms of 'mowdies,' *i.e.*, moles, came out of the ground that the diggers were put to flight.

685. *Kirkpatrick-Durham.*—When St. Patrick left Kirkpatrick-Durham, he blessed a well close beside the churchyard. On March 17 the one that was suffering from any disease that first went to the well, drew water from it, and drank it was healed of the ailment. A woman drowned a child in it, and the healing virtue departed from its water. (Told in Kells.)

686. *Kirkcudbright.*—When the branches of an ash-tree growing out of the old castle wall, and the branches of a berry-bush growing out of the wall of the old school meet, the town of Kirkcudbright and the district of the country ten miles round it will sink below the level of the sea. The branches of the ash tree have been cut several times.

Caves.

687. *Kirkmaiden.*—In the parish of Kirkmaiden, at the Mull, there is a cave, and in the cave there is a stone. My informant saw about thirty years ago buttons, pins, pieces of iron and rags lying on it and around it.

688. *Kirkmaiden.*—In the parish of Kirkmaiden there is on the edge of the public road on the east side of the parish a cave called the Grenan Cave. A dog on one occasion entered it on the east side, and came out on the west side of the point at a place called Slockmona.

689. *Parton.*—There was a time not long ago when a field on the farm

of Dullarg, parish of Parton, lay unploughed. The saying was: 'The man that ploughed the ley would never cut the crop.' Peter McCutcheon the farmer ploughed the field and sowed it. He died before the crop was reaped. The field has been cropped since. (Told in Kells by an old man.)

690. *Tungland.*—On the farm of Balannan, Tungland, there are two fields adjoining each other, the one called The Drum, and the other The Croft, which have never been cultivated. The belief is that if cultivated, the death either of proprietor or tenant will be the consequence. Both fields were reserved during the last lease. They are not now reserved, but they still lie untilled.

691. *Kelton.*—It is the belief that Carlinwark Loch, near Castle Douglas, must have a victim yearly. (Told in Kells by an old man.)

Place Rhymes, &c.

692. *Balmaghie.*—

The mealpoks of Girthon,
The bannocks of Borgue,
The puir boddies of Balmaghie.

693. *Dalbeattie.*—

The men of Kelton,
The Redshanks of Balmaghie.

694. *Mochrum.*—The Mochrum Scarts
695. *Balmaghie.*—The town of Kirkcudbright is called Whisky Jane.
696. *Mochrum.*—

There's Cairnsmohr o' Fleet (Kirkcudbright)
  There's Cairnsmohr o' Dee,
And Cairnsmohr o' Deuch (or Carsphairn),
  The highest o' the three.

697. *Mochrum.*—

When Cairnsmohr puts on his hat,
The Mochrum Lochs may lauch at that.

698. *Corsock.*—

When Mochrum hill puts on her hat,
Millhairy hears word o' that.

699. *Kells*—

When Louran's broo (Kells) gets on its cap,
The river Dee lauchs at that.

700. *Rerrick.*—

When Cairnharrow (Anwoth) puts on her cap,
Cairnsmuir may leuk at that.

701. *Corsock.*—

When Skiddaw pits on her hat,
Criffel soon hears word o' that.

702. *Crossmichael.*—

To Dee said Tweed
'What gars ye rin sae slaw,
While I rin wi' speed?'
To Tweed said Dee,
'Though ye rin fast,
And I rin slaw,
Whaur ye droon ae man
I droon twa.'

Rhymes on parts of the body.

The Fingers.

703. *Balmaghie.*—

This is the yin that broke the barn,
This is the yin that stelt the corn,
This is the yin that tellt a',
An' puir Pirlie Winkie paid for a'.

704.—*Kirkmaiden.*—

There's the yin that broke the barn,
There's the yin that stole the corn,
There's the yin that ran awa',
Peer wee Peerie Winkie paid for a'.

705. *Minnigaff*, 80 years ago.—

This is the man that broke the barn,
And this is the man that stole the corn,
And this is the man that sat and saw,
And this is the man that ran awa',
And this is Peerie Winkie paid for a'.

706. *Portlogan.*—

Here's the yin that broke the barn,
Here's the yin that stole the corn,
Here's the yin that stood an' saw,
Here's the yin that tellt a',
An' peer wee Weerie Winkie paid for a'.

707. *Kirkmaiden.*—

This is the yin that broke the barn,
This is the yin that stole the corn,
This is the yin that ran awa',
This is the yin that sat an' saw,
An' peer Peerie Winkie paid for a'.

708. *Rerrick.*—

This is the yin that broke the barn,
This is the yin that stole the corn,
This is the yin that sat and saw,
This is the yin that tellt a',
Wee Pirlie Winkie.

The Legs.

709. *Kirkmaiden.*—

Twa wee dogs geed t' the market,
An' they fell oot aboot a bane,
An' he ower him an' he ower him.

710. *Minnigaff.*—

Twa wee dogs, they geed t' the mill,
They opent their pokes an lickit their fill,
An' the yin said: 'Gee me a lick oot o' your poke,
An' I'll gee you a lick oot o' mine;'
An' up the street they ran, they ran.

711. *Kirkmaiden.*—

There wiz twa wee dogs geed t' the mill,
An' the twa wee dogs lickit their fill,
The yin took a lick oot o' yin man's poke,
An' yin oot o' the ither,
An' hame they cam, an' hame they cam.

712. Twa wee dogs geed t' the mill,
Waik an feeble, waik an feeble,
They geed to the hopper an lickit their fill,
An they cam hame stoot an' able, stoot an' able.

713. *Portlogan.*—

Twa wee dogs went t' the mill,
They opent a bag an lickit their fill,
Ae aul' woman gya them a lick,
Anither aul' woman gya them a lick,
An they cam hame fit for fit.

The Face.

714. *Rerrick.*—

Broo brentie,
E'e winkie,
Nose nentie,
Mooth merry,
Chin cherry.

715. *Kirkmaiden.*—

There's where the cat sat (brow),
There's where the cat lay (nose),
There's where she broke her bone (chin).

Knees—when dandling a child.

716. *Kirkmaiden.*—

Ladies, ladies, into the yate (gently),
Gentlemen, gentlemen, into the yate (more rapidly),
Creel-cadgers, creel-cadgers, after a' (roughly).

The Feet.

717. *Corsock.*—

'Johnny Smith, a fellow fine,
Can ye shee this horse o' mine?'
'Yes, indeed, and that I can,
Jist as weel as any man.
Here's the hammer, here's the nails,
Ca tee, ca tee.'

718. *Balmaclellan.*—

'John Smith, a fellow fine,
Can ye shee this horse o' mine?'
'Yes, indeed, and that I can,
Here's a hammer, here's a shoe,
Ca too, ca too.'

719. *Rerrick.*—

'John Smith, a fallow fine,
Can ye shue this horse o' mine?'
'Yes, indeed, and that I can,
Jist as weel as ony man;
Here's a nail upon the tae
T' make the horse climb the brae
Here's a nail upon the heel
T' make the horse gallop weel;
Then pay me, then pay me, sir.'

720. *Minnigaff.*—

'Jock Smith a fallow-mine (?)
Can ye shoe this horse o' mine?'
'Yes, indeed, and that I can
As weel as ony other man.
Here's the hammer, here's the brod;
Gentleman, yer horse is shod.'

721. *Portlogan.*—

'John Smith a fulla fine,
Could you shoe this horse o' mine?'
'Yes, indeed, an' that I could
As weel as ony boddie.
Here's a nail, and there's a prod,
Ca too, ca too,
Gentleman, yer horse is shod.'

722. *Kirkmaiden.*—

'John Smith o' Manybole,
Can ye shee a wee foal?'
'Yes, indeed, an' that I can,
Just as weel as any man.
Here's the hammer an' here's the shod,
Ca it on, ca it on.'

General.

723. *Kirkmaiden.*—

Saw-see, cut a wee tree,
An' big a wee boat,
An' sail awa' t' Donaghadee
For sugar an' tea,
To (child's name) an' me.

724. Saw-see, cut a wee tree,
T' big a wee boat,
T' sail on the sea,
T' catch a wee fish,
T' put in the dish
For wee (child's name) an' me.

725. *Forfar.*—

Aul John Reid
Was chockit t' deed
Wi' eatin' a piece o' butter an' breed;
It was na for need
Bit jist for greed
That aul' John Reid
Was chockit for deed.

726. *Kells.*—

Hoot awa', North win',
Mack the windows shiver,
Hoot awa', enjoy your play,
I shall be warm as ever.

727. *Balmaghie.*—

Hush ye, baby, do not fret ye,
The Black Douglas shall not get ye.

728. *Portwilliam.*—

. . . is my name,
And Scotland is my nation,
Wigton is my dwelling place,
And Christ is my salvation.

[Copied from a book, and dated 1802.]

729. *Rerrick.*—During a hail shower the following words are repeated :

Rainie, rainie, rattle stanes,
Dinna rain on me ;
Rain on Johnnie Grant's house,
Far ayont the sea.

730.—The following lines were observed written on a gate near Auchincairn House, Rerrick :

Be ye man or be ye woman,
Be ye gun or be ye cannon,
Be ye early or be ye late,
Don't forget to shut this gate.

Counting-out Rhyme.

731. *Portlogan.*—

Seetum, peetum, potum, pie,
Paper, lotum, jinkum, jye,
Stan' ye there oot bye.

When all are counted out except two—
Two an' two's a tippenny loaf,
Two an' two's oot.

732. *Georgetown.*—

Eerie, orie, aikerie, ann,
Fill ma pock an' lat me gang ;
Black fish, white troot,
Eerie, orie, ye're oot.

733 *Rerrick.*—

Eetum, peetum, penny pie,
Ye're a fool as well as I.

APPENDIX II.

Report on the Ethnography of Wigtonshire and Kirkcudbrightshire.

The data for this Report were collected with great care by the late Dr. Walter Gregor, and the Committee regret that our esteemed colleague did not live to receive the congratulations which they feel are due for this valuable piece of work. The schedules have been tabulated and the indices recorded by Dr. A. C. Haddon, who desires to express his thanks

to Mr. E. W. Brabrook for assistance rendered. The following is the record of the work done in 1896 by Dr. Gregor in his own words :—

'On April 14 I went to the parish of Kirkmaiden as the guest of James McDonall, Esq., of Logan. By his help personally, and through him, by the help of the Rev. Mr. Cavan, Free Church minister at Dromore, and the Rev. Mr. Guttridge, Episcopalian clergyman at Logan, twenty-one sets of measurements were obtained, fifteen of males and six of females. On Monday, April 20, I proceeded to the Manse of Minnigaf, where I was again cordially received by Mr. and Mrs. Reid. As on my former visit, Mr. Reid afforded me every assistance he could, and eleven sets of measurements were taken, five of males and six of females. On Friday, April 24, I went to the Manse of Mochrum, and had the help of Mr. Allan and his daughter. In that parish were got eleven sets of measurements, seven of males and four of females. On the kind invitation of Mr. Reid, minister of Balmaghie, I went to his manse on April 28, My stay in that parish produced seven sets of measurements, six of males and one of a female. The Manse of Kells was my next destination, which I reached on May 6. There I had the help and influence of Mr. Philip. In that and the neighbouring parish of Dalry only three sets of measurements were taken as my schedules were exhausted. Fifty-three sets of measurements form the result of this second visit, thirty-six of males and seventeen of females.

'As on my former visit I tried to find out those whose ancestors have lived for the longest period in Galloway in the line both of father and mother.

'In all the districts I visited every opportunity of collecting the folk-lore was laid hold of, and a good deal of it, some of which will prove of interest, was gathered. It may be stated that when natives of other districts were met with, they were questioned, and what information was obtained was noted down, and the county it comes from was stated. It will take a considerable time to make ready my notes, but the work will be carried out as speedily as I can.

'The Committee are again under great obligation to all those who have exerted themselves to carry out this investigation.

'I have to state that everywhere I was received with the utmost cordiality, and the hospitality and true kindness accorded to me by my hosts and their families are beyond all thanks.

'I have the honour to send to the Committee the fifty-three schedules.'

Dr. Gregor has filled up schedules for 46 Wigtonshire and 36 Kirkcudbrightshire men (total 82), and for 21 Wigtonshire and 13 Kirkcudbrightshire women (total 34), making a gross total of 116 Galloway folk. These observations have been tabulated according to counties and sexes. As there is no appreciable difference between the inhabitants of the two counties, at all events so far as the men are concerned, we may describe the Galloway type in the following terms :—

Men.

The average height of the men is 1733 mm. (5 ft. 8¼ in.), the maximum being 1853 mm. (6 ft. 3 in.) and the minimum 1587 mm. (5 ft. 2½ in.). The average height sitting is 905 mm. (2 ft. 11¾ in.).

The skin is ruddy; it is not stated whether there is a tendency to freckle. The hair usually is darkish brown and straight; the actual

figures are red 6, fair 16, brown 32, dark brown 24, black 3. (51 out of 82 are credited with straight hair, but the proportion is probably greater.) The eyes are as follows:—blue 35, light grey 25, dark grey 8, green 1, light brown 5, dark brown 8. Only a few (15) are stated to have prominent cheek bones. The nose is straight, with a slight tendency to sinuosity. The ears are flat with distinct lobes.

The average cephalic index is 77·4, varying between 70·3 and 82·6. No deduction has been made to reduce it to the cranial index of the skull. The average length-height index is 66·8, and the breadth-height index 86·9. The average upper facial index 49, and the nasal index 60·4.

Women.

The average height of the women is 1600 mm. (5 ft. 3 in.), the maximum being 1710 (5 ft. 7¼ in.) and the minimum 1423 mm. (4 ft. 8 in.) The Kirkcudbrightshire women are somewhat shorter (1578 mm.—5 ft. 2 in.) than the Wigtonshire women (1621 mm.—5 ft. 3¾), though this is not the case with the men, but the numbers are insufficient to lay any stress on this fact. The skin is usually ruddy. The colour of the hair varies more than among the men. Thus for Wigton the figures are—red 3, fair 5, brown 4, dark brown 5, black 4; and for Kirkcudbright, red 1, fair 1, brown 8, dark brown 3, black 0. It is generally straight. The eyes are as follows:—Wigton: Blue 6, light grey 2, dark grey 3, green 0, light brown 2, dark brown 8. Kirkcudbright: Blue 3, light grey 5, dark grey 1, green 0, light brown 2, dark brown 1. Thus the Wigtonshire women are somewhat darker than those of Kirkcudbrightshire. The other facial features resemble those of the men.

The average cephalic index is 78·4, varying between 71·5 and 88·5. The average length-height index is 68, and the average breadth-height index 87; that of the Wigtonshire women is 88·4, and that of the Kirkcudbrightshire is 85·7, as the breadth is precisely the same in both instances (147 mm.); the difference in the index is due to the average height of the cranium being greater in the Wigton (130 mm.) than in the Kirkcudbright (126 mm.) women. The upper facial index is 47, and the nasal index 61·2. Thus, besides being slightly more brachy-cephalic, or rather less dolicho-cephalic than the men, the Galloway women have relatively broader faces and wider nostrils.

The tables upon which this abstract is based have been handed to the Anthropological Institute for publication.

The district surveyed by Dr. Gregor is of especial interest, as it is included in the country of the ancient Picts, a people concerning whose affinities various theories have been made. When the Ethnographical Survey of Great Britain and Ireland was originated, it was intended that this should be one of the first problems to be attacked. A comparison with the results obtained from other areas formerly inhabited by the Picts will show whether the above-described type is mainly that of the Picts, or whether it is a composite type, which will require a finer analysis. However this may be, we have at least advanced a definite stage towards the solution of this important historical and anthropological problem. Dr. Beddoe's 'The Races of Britain,' p. 249, should be consulted on this subject.

APPENDIX III.

Report of the Cambridge Committee for the Ethnographical Survey of East Anglia.

The Committee present the reports on the physical characters of the inhabitants of two districts in the neighbourhood of Cambridge.

Last year Professor Macalister gave a course of lectures on Anthropology at Aberdeen, which excited a good deal of local interest. Several members of his audience were stimulated to study the subject, and some of their personal observations on the hair and eye colours of the inhabitants of Aberdeen and elsewhere are here appended.

Professor Macalister also interested Mr. J. J. Taylor, M.B., of Emmanuel College, Cambridge, in making anthropometrical observations. Mr. Taylor took the opportunity of a bazaar to measure and note the characters of 66 natives of Yorkshire. The following tables give details of 31 of these who came from a restricted area.

Some former students of Professor Haddon's took a similar opportunity in Belfast in 1894 and measured a large number of people. In both cases the visitors to the bazaars paid a small sum to be measured, and they received a printed form on which was entered a copy of their measurements. This method of obtaining measurements and other anthropological data might very well be employed elsewhere.

On the Physical Characters of the Inhabitants of Barley, Herts. *By* A. C. Haddon.

In the 1895 Report of the Association a reference was made (p. 510) to observations I made, with the assistance of some of my students, on the physical characters of the inhabitants of the parish of Barley. Though situated in Hertfordshire this village is on the borders of Cambridgeshire and Essex. The rector, the Rev. J. Frome Wilkinson, afforded me every facility in his power, and induced several of his parishioners to be measured.

The families of thirteen of the men measured at Barley have been established in the district for some two or three hundred years. The parents of No. 8 came from Braintree in Essex, and those of No. 14 from Suffolk, where, in both instances, their families had been for generations. I have included them in the totals, as they do not appreciably affect the averages; No. 8 is, however, less typical.

The average Barley man may be described as having a ruddy skin, which does not freckle; brown hair, with a tendency to fair or red, though dark hair is by no means uncommon. The hair is as often straight as wavy. Eight have blue eyes, two each light and dark grey, one green, and two light brown. The face is in an equal number of cases of medium breadth, or long or narrow. Nos. 12 and 15 have broad faces. The cheek bones are inconspicuous. The nose is most usually straight—two had turned-up noses. The lips are thin or of medium thickness. The ears are, as a rule, fairly prominent, but they are not of a coarse type. The average stature (excluding No. 15) is 1,695 mm., or 5 feet $6\frac{3}{4}$ inches.

The more important head measurements and indices will be found in the table. Full face and profile photographs were taken of the fifteen individuals measured; copies of these are deposited with the schedules containing the detailed information.

No.	Males	Skin	Hair	Eyes	Height	Cranial						Total Facial			Upper Facial		Interocular Breadth	Nasal		
						Length	Breadth	Index	Height	Length Height Index	Breadth Height Index	Length	Breadth	Index	Length	Index		Length	Breadth	Index
1	19	ruddy	brown	blue	1,679	184	151	82·1	134	72·8	88·7	120	136	80·8	70	51·5	32	53	34	64·2
2	21	”	fair	dark grey	1,745	198	156	78·8	135	68·2	86·5	121	140	86·4	72	51·4	33	58	35	60·3
3	56	”	”	light grey	1,804	195	156	80·0	133	68·2	85·3	129	142	90·8	74	52·1	30	55	33	60·0
4	49	”	”	blue	1,656	200	153	76 5	122	61·0	79·7	120	141	85·1	73	51·7	29	57	34	59·6
5	66	—	black	”	1,763	206	150	72·8	128	62·1	85·3	120	139	86·3	72	51·8	30	59	39	66·1
6	32	pale	brown	light brown	1,745	188	153	81·4	121	64·4	79·1	126	137	92·0	78	57·0	29	57	33	57·9
7	45	ruddy	dark	blue	1,564	184	149	81·0	130	70·7	87·2	116	130	90·0	67	50·1	29	54	30	55·6
8	40	pale	brown	light grey	1,695	209	160	76·5	118	56·4	73·8	123	138	89·1	72	52·2	26	48	37	77·1
9	29	”	”	light brown	1,693	200	158	79·0	135	67·5	85·4	114	142	80·3	66	46·5	27	44	35	79·5
10	47	ruddy	red	dark grey	1,588	191	153	80·1	130	68·1	85·0	119	133	90·0	68	51·1	29	53	38	71·7
11	51	pale	”	blue	1,772	195	154	79·0	136	69·7	88·3	119	136	87·5	61	44·8	31	46	37	80·4
12	40	ruddy	black	green	1,702	187	150	80·2	120	64·2	80·0	113	143	79·0	71	49·6	24	55	38	69·1
13	43	”	dark	blue	1,630	190	154	81·1	130	68·4	84·4	113	133	85·0	63	47·3	27	45	37	82·2
14	49	pale	black	”	1,698	199	156	78·4	127	63·8	81·4	118	138	85·3	67	48·5	29	51	36	70·6
15	49	ruddy	brown	”	1,490	184	154	83·7	130	70·7	84·4	91	141	64·5	60	42·4	25	42	33	78·6
Average	—	—	—	—	1,681	—	—	79·4	—	66·4	83·6	—	—	80·8	—	49·5	—	—	—	64·0

On the Physical Characters of the Inhabitants of the Villages of Barrington and Foxton, in Cambridgeshire.
By O. F. F. Grünbaum, *B.A., Trinity College.*

No.	District	Sex	Skin	Hair	Eyes	Lips	Height	Cranial			Facial			Length Upper Face	Index	Inter-ocular Breadth	Nose		Index
								Length	Breadth	Index	Length	Breadth	Index				L.	B.	
1	Barrington . .	M.	ruddy	dark	light brown	medium	1,658	183	157	85·8	123	142	88·6	72	49·9	32	54	36	66·7
2	„ . .	„	pale	„	green	„	1,630	180	152	84·4	120	131	91·6	70	53·4	31	51	34	66·7
3	„ . .	„	ruddy	fair	blue	„	1,533	185	152	82·2	124	139	89·2	70	49·9	29	50	32	64·0
4	„ . .	„	pale	dark	light grey	„	1,602	190	152	80·0	112	135	83·0	62	45·9	26	56	32	57·1
5	„ . .	„	ruddy	brown	„	„	1,740	198	158	79·8	115	135	85·2	75	55·5	24	50	32	64·0
6	Wimpole . .	„	dark	„	blue	„	1,720	189	150	79·4	117	144	81·3	72	50·0	32	32	37	71·2
7	Barrington . .	„	„	„	„	„	1,640	190	150	78·9	118	140	84·3	71	51·7	35	50	35	70·0
8	„ . .	„	pale	fair	dark grey	„	1,733	190	150	78·9	124	132	93·9	73	55·0	28	—	—	—
9	„ . .	„	dark	brown	light grey	„	1,655	188	148	78·7	130	124	95·4	72	58·0	32	58	34	58·6
10	„ . .	„	ruddy	red	„	thin	1,595	194	152	78·4	118	124	95·2	67	54·0	28	44	36	81·8
11	„ . .	„	„	dark	dark grey	„	1,640	190	147	77·4	116	135	85·9	63	46·6	38	57	28	66·7
12	Elmden . .	„	dark	brown	green	thick	—	187	144	77·0	128	115	89·8	71	61·7	28	53	26	49·1
13	Barrington . .	„	ruddy	fair	„	medium	1,665	186	143	76·9	127	133	95·5	75	56·4	30	54	32	59·1
14	„ . .	„	„	brown	light brown	„	1,744	200	151	76·9	108	136	79·4	76	55·9	19	51	30	58·8
15	Foxton . .	„	pale	„	blue	thick	1,680	190	148	77·9	108	133	81·2	66	49·6	27	56	26	46·4
16	„ . .	„	dark	dark	dark grey	medium	1,700	193	150	77·7	114	140	81·4	65	46·4	36	50	41	82·0
17	Foulmere . .	„	ruddy	„	blue	„	1,655	190	144	75·8	116	132	87·8	70	53·1	29	50	28	56·0
18	Barrington . .	„	„	brown	„	thin	1,607	200	151	75·5	121	137	88·3	68	49·6	33	46	36	78·0
19	Cumberton . .	„	„	—	light grey	„	1,725	202	151	74·8	146	131	111·4	78	59·5	27	60	36	60·0
20	Barrington . .	F.	„	dark	dark brown	medium	1,515	173	143	82·7	110	127	86·6	64	50·4	31	46	30	65·2
21	„ . .	„	„	„	light grey	„	1,584	184	138	75·4	114	118	96·6	64	54·2	32	54	32	59·0
22	Foxton . .	M.	„	„	green	„	1,740	202	158	78·2	126	132	95·5	63	47·7	34	50	31	62·0
23	„ . .	„	„	brown	blue	„	1,630	190	152	80·0	113	145	77·9	64	44·2	33	53	36	67·8
24	„ . .	„	„	dark	green	„	1,610	178	—	—	116	142	81·7	65	45·8	29	53	32	60·4

None of the people in the neighbourhood of Barrington and Foxton had projecting cheek-bones; the ratio, however, between length and breadth of face varied widely, as seen under the Facial Indices in the table.

The complexion varied, 15 being ruddy, 5 dark, and 4 pale; dark hair predominated, 10 individuals possessing it of that shade, 9 brown, 1 red, and 3 fair.

The colour of the eyes was chiefly light: 7 blue, 6 light grey, 2 light brown, 5 green, 3 dark grey, and 1 dark brown.

Lips were mostly of medium thickness, 4, however, having thin and 2 thick lips.

Height of men variable, from 1,533 to 1,744 mm.

The cephalic index would show by itself that the people are a very mixed production, and this is corroborated by the rest of the indices.

From a cursory study of the table, it seems impossible to separate the people into any series of types, or to determine any common type.

Photographs of most of the individuals accompany the table, along with further details not mentioned above.

APPENDIX IV.

Observations on Physical Characteristics of Children and Adults taken at Aberdeen, in Banffshire, and in the Island of Lewis.

1. *Table of the Colour of the Hair and Eyes of* 720 *School Children attending the Skene Street Public School, Aberdeen. Collected by the Headmaster,* ALEXANDER FORBES, *Esq. January* 1896.

Standards . . Average Ages .	Infant 6	I. 7	II. 8	III. 9	IV. 10	V. 11	VI. 12	Total
Hair: Dark . .	42	23	32	30	26	16	14	183
Hair: Medium .	74	55	43	40	46	56	18	332
Hair: Fair . .	63	38	28	28	19	21	8	205
Total . .	179	116	103	98	91	93	40	720
Eyes: Dark . .	51	16	30	20	16	22	10	165
Eyes: Medium .	67	61	25	32	49	39	19	292
Eyes: Light .	61	39	48	46	26	32	11	263
Total . .	179	116	103	98	91	93	40	720

2. *Table of the Colour of the Hair and Eyes of* 184 *Inhabitants of Aberdeen. By* MR. JAMES W. DUNCAN.

—	Hair			Total
	Fair	Medium	Dark	
Eyes: Blue . . .	55	13	22	90
Eyes: Medium . .	22	16	23	61
Eyes: Dark . . .	13	4	16	33
Total . . .	90	33	61	184

3. *Table of the Colour of the Hair and Eyes of* 120 *Inhabitants of Aberdeen. By* Mr. J. Cooper.

—	Hair			Total
	Fair	Medium	Dark	
Eyes: Light	17	8	1	26
Eyes: Medium	25	21	8	54
Eyes: Dark	12	16	12	40
Total	54	45	21	120

4. *Table of the Colour of the Hair and Eyes of the Inhabitants of Cullen, Banffshire.* 104 *observations, exclusive of the Fishing Population, by* Mr. John Smith. 149 *observations on the Fishing Population, by* Mr. J. B. Gardiner.

—	Hair			Total	Hair			Total
	Fair	Med.	Dark		Fair	Med.	Dark	
Eyes: Light	20	28	9	57	47	29	11	87
Eyes: Medium	6	18	12	36	12	13	24	49
Eyes: Dark	1	1	9	11	—	4	9	13
Total	27	47	30	104	59	46	44	149

5. *Table of the Colour of the Hair and Eyes of* 283 *Inhabitants of Luirbost, Stornoway, Lewis, Hebrides. By* Mr. K. S. Macleay.

—	Hair			Total
	Fair	Medium	Dark	
Eyes: Blue	47	60	23	130
Eyes: Medium	32	35	15	82
Eyes: Dark	25	22	24	71
Total	104	117	62	283

APPENDIX V.

Anthropometric Notes on the Inhabitants of Cleckheaton, Yorkshire. By J. J. Taylor.

The following tables embody the results of a series of measurements, made in November 1896, in connection with a bazaar at Cleckheaton, a manufacturing town about six miles south of Bradford, Yorkshire.

In compiling the tables only persons over the age of twenty, and born within a radius of two miles, have been included.

It has resulted from the method of obtaining the data that the number of the working-class measured was small, comprising among

TABLES I. and II.

No.	Sex	Age	Birthplace	Skin	Hair Colour	Hair	Eyes	Height	Span of Arms	Face	Cheeks	Facial Length	Facial Breadth	Facial Index	Head Length	Head Breadth	Cephalic Index	Nasal Length	Nasal Breadth	Nasal Index	Profile of Nose
1	M.	20	Cleckheaton .	P	F.	St.	M.	1,728	1,754	M.	In.	120	127	94·5	200	150	75·0	53	33	62·3	St.
2	„	21	„ .	R.	D.	St.	D.	1,563	1,623	B.	In.	115	129	89·1	188	149	79·3	53	34	64 1	St.
3	„	23	„ .	P.	F.	St.	L.	1,836	1,901	L.	In.	121	132	91·7	192	147	76·1	50	35	70·0	St.
4	„	23	„ .	D.	D.	St.	M.	1,684	1,791	M.	In.	120	137	87·6	192	155	80·7	53	35	66·0	St.
5	„	23	„ .	P.	B.	W.	D.	1,709	1,779	B.	In.	128	137	93·1	191	147	76·9	53	34	64·1	St.
6	„	24	„ .	P.	D.	St.	D.	1,734	1,799	L.	In.	117	132	88·6	182	155	85·2	55	29	52·7	St.
7	„	25	„ .	P.	B.	St.	D.	1,713	1,890	L.	P.	130	139	93·5	203	163	80·3	63	34	54·0	2
8	„	25	„ .	P.	D.	W.	D.	1,778	1,842	L.	In.	128	127	100·8	199	152	76·4	55	35	63·6	1
9	„	25?	„ .	P.	D.	St.	D.	1,714	1,766	L.	In.	108	129	83·7	193	149	77·2	55	34	61·8	St.
10	„	30	„ .	R.	D.	St.	D.	1,721	1,741	M.	In.	126	141	89·3	190	151	79·5	57	35	61·4	St.
11	„	30	„ .	R.	D.	St.	D.	1,706	1,756	B.	P.	126	135	93·3	190	153	80·5	57	33	57·9	St.
12	„	35	„ .	R.	B.	St.	M.	1,744	—	B.	In.	119	146	81·5	210	160	76·2	51	38	74·5	St.
13	„	35	„ .	R.	D.	St.	D.	1,650	1,689	B.	In.	122	127	96·1	195	159	81·5	51	38	74·5	St.
14	„	48	„ .	P.	B.	St.	M.	1,830	1,914	L.	In.	132	144	91·7	208	162	77·9	60	34	56·7	St.
15	„	50	„ .	R.	B.	St.	M.	1,692	1,627	M.	P.	116	135	85·9	194	158	81·4	54	31	57·4	St.
16	„	20	Liversedge .	P.	B.	St.	M.	1,679	1,734	M.	In.	119	137	86·8	197	155	78·7	48	32	66·7	St.
17	„	38	„ .	P.	B.	St.	M.	1,675	1,684	B.	In.	117	130	90·0	197	154	78·2	53	35	66·0	St.
18	„	23	Gomersal .	R.	B.	St.	D.	1,656	1,698	B.	In.	115	145	79·2	196	156	82·1	46	32	69·6	2
19	„	23	„ .	P.	D.	W.	D.	1,648	1,723	B.	In.	124	135	91·8	192	155	80·7	55	31	56·4	1
20	„	60	„ .	R.	B.	St.	M.	1,615	1,670	B.	In.	111	142	78·2	184	157	85·3	49	40	81·6	St.
1	F.	20	Cleckheaton .	P.	F.	W.	D.	1,574	1,576	L.	In.	119	123	96·7	—	—	—	53	26	49·1	St.
2	„	20	„ .	P.	B.	W.	M.	1,564	1,637	L.	In.	105	129	81·4	175	142	81·1	53	32	60·4	St.
3	„	21	„ .	P.	B.	W.	D.	1,557	1,556	B.	In.	110	126	87·3	185	142	76·8	51	30	58·8	St.
4	„	21	„ .	P.	B.	W.	M.	—	1,464	B.	P.	111	143	77·0	178	147	82·6	49	33	67·3	St.
5	„	21	„ .	R.	B.	W.	M.	1,656	1,619	M.	In.	110	129	85·3	183	150	81·8	48	28	58·3	St.
6	„	22	„ .	P.	F.	St.	M.	1,507	1,543	M.	In.	113	129	87·6	177	140	79·1	54	33	61·1	2
7	„	25	„ .	R.	D.	St.	M.	1,554	1,629	M.	In.	98	125	78·4	170	138	81·2	50	31	62·0	St.
8	„	—	„ .	D.	D.	St.	D.	—	1,606	M.	In.	—	—	—	—	—	—	—	—	—	St.
9	„	—	„ .	R.	D.	St.	D.	—	1,588	M.	In.	—	—	—	—	—	—	—	—	—	St.
10	„	—	„ .	P.	D.	St.	D.	—	—	M.	—	—	—	—	—	—	—	—	—	—	St.
11	„	—	Hartshead .	P.	D.	St.	D.	1,578	1,588	M.	In.	125	117	106·8	187	151	80·7	53	32	60·4	St.

the men Nos. 7, 9, 10, 11, and 20, Nos. 4, 6, and 13 being doubtful; and among the women we get Nos. 6 to 11. All the men of this class, with the exception of No. 20—who is a gardener—are engaged in indoor work, and most probably all the women likewise are, or have been, employed in factories.

Tables I. and II. (see p. 508) show the various individual measurements, indices, &c.

The skin colour being divided into pale, ruddy, and dark.

The hair colour being divided into fair, red, brown, dark, and black.

The hair into straight and wavy.

The eyes into light, medium, and dark.

The face was divided, according to the general impression given by a full-face view, into long, medium, or broad.

The cheek-bones were divided according as they appeared to be inconspicuous or prominent.

The profile of the nose was divided into straight (St.), hooked (1), and sinuous (2).

All measurements were taken in millimetres.

Tables III. and IV. give the mean indices of all the men and women respectively, and also their mean indices when grouped according to their eye colours.

Tables V. and VI. are arranged in a similar way for their hair colour.

Tables VII. and VIII. give the relations of hair colour to eye colour.

Tables III. and IV.

	Sex	No.	Facial Index	No.	Cephalic Index	No.	Nasal Index
Mean . .	M.	20	89·3	20	79·5	20	64·7
Light Eyes .	,,	1	91·7	1	76·6	1	70·0
Medium Eyes .	,,	8	87·0	8	79·2	8	66·4
Dark Eyes .	,,	11	90·8	11	80·0	11	61·8
Mean . .	F.	8	87·1	7	80·5	8	59·5
Light Eyes .	,,	—	—	—	—	—	—
Medium Eyes .	,,	5	81·3	5	81·2	5	61·8
Dark Eyes .	,,	3	96·9	2	78·8	3	56·1

Tables V. and VI.

	Sex	No.	Facial Index	No.	Cephalic Index	No.	Nasal Index
Mean . .	M.	20	89·3	20	79·5	20	64·7
Fair Hair . .	,,	2	93·1	2	76·3	2	66·1
Brown Hair .	,,	9	85·3	9	79·2	9	66·6
Dark Hair .	,,	9	91·1	9	80·1	9	62·0
Mean . .	F.	8	87·1	7	80·5	8	59·5
Fair Hair . .	,,	2	92·1	1	79·1	2	55·1
Brown Hair .	,,	4	81·9	4	80·6	4	61·2
Dark Hair .	,,	2	92·6	2	80·9	2	61·2

TABLES VII. AND VIII.

	Sex	No.	Light Eyes	Medium Eyes	Dark Eyes
Fair Hair	M.	2	1	1	0
Brown Hair	"	9	0	6	3
Dark Hair	"	9	0	1	8
No.	"	20	1	8	11
Fair Hair	F.	2	0	1	1
Brown Hair	"	4	0	3	1
Dark Hair	"	5	0	1	4
No.	"	11	0	5	6

Thirteen per cent. have fair hair, 42 per cent. brown hair, and 45 per cent. dark hair; the nigrescence index of Beddoe is 10 for the total of 31, or 32·2 per cent.

APPENDIX VI.

Report of the Committee on the Ethnographical Survey of Ireland, consisting of Dr. C. R. BROWNE, Professor D. J. CUNNINGHAM, Dr. S. HAUGHTON, Professor E. PERCEVAL WRIGHT, *and* Professor A. C. HADDON (*Secretary*).

Last summer (1896) Dr. Browne visited Clare Island and Inishturk, co. Mayo. Until lately both these islands have been greatly cut off from the outer world; indeed, the latter is still without a postal service; but Clare Island has recently been bought by the Congested Districts Board, and so great changes may be expected in the people.

The population of Clare Island belongs largely to the Clan U'Maille (O'Malley). Inishturk is populated by the O'Tooles. Some think this is a branch of the Leinster sept of that name, but the people claim that they are a branch of the O'Malleys.

Dr. Browne measured 56 adult males, and noted the eye and hair colours of 206 individuals. The people are fairly good-looking, brown-haired and blue-eyed, and of rather slender build. The average height is 1,696 mm. (5 ft. $6\frac{3}{4}$ in.), somewhat below the average Irish stature; the cephalic index is 79·4. The face is very broad; the nose is often short and upturned, and is broad across the nostrils, giving a high nasal index (69·1 for Inishturk). The physical proportions differ a good deal from those of other districts in co. Mayo. The people of Inishturk are taller (1,716 mm.), stouter, darker, and of lower cephalic index (77·9) than those of Clare Island (1,693 mm. and 79·7 respectively).

The mode of life is somewhat similar to that in Inishbofin.[1] The greater part of the islands is held in commonage, and all land when not actually in crops is common land. Very little land is cultivated, and all of it by spade labour. A good deal of kelp is burnt.

In his paper, which was read before the Royal Irish Academy in June,

[1] *Proc. Roy. Irish Acad.*, 3rd series, vol. iii. 1894, p. 317.

Dr. Browne gives numerous other details of the physical and mental characteristics of the people, their dress, habitations, and mode of life, together with interesting items of folklore.

The account of the work of the previous year (1895) was published by the Royal Irish Academy last December, 'The Ethnography of Ballycroy, co. Mayo.'[1]

Silchester Excavation.—Report of the Committee, consisting of Mr. A. J. EVANS (*Chairman*), Mr. JOHN L. MYRES (*Secretary*), *and* Mr. E. W. BRABROOK, *appointed to co-operate with the Silchester Excavation Fund Committee in their Explorations.*

THE Committee beg leave to report that the excavations on the site of the Roman City at Silchester during the year 1896 were begun on May 1 and continued, with the usual break during harvesting operations, until October 26.

The area selected for excavation included two *insulæ* (XV. and XVI.), immediately south of *insulæ* XIII. and XIV., which were excavated in 1895. The result was, on the whole, satisfactory, and as usual ended in some curious and totally unexpected discoveries.

Insula XV. appears, like *insulæ* IX., X., XI., XII., and XIII., to have been given up to the dyeing industry, of which traces were found in 1894 and 1895, and a large area in the northern part of the *insula* was perhaps used as a bleaching ground. Two wells were discovered, one with a wooden framing at the bottom, the other with a large wooden tub, which will be added with other antiquities to the Silchester Loan Collection in the Reading Museum.

Insula XVI. contained a large and important house of the courtyard type in the north-west angle, and two other houses of the corridor type, as well as an isolated square building. Traces were also found of other structures, which were probably of wood. A large number of pits were met with in the trenches, and from these some good vessels of pottery and other antiquities were recovered. A pit of unusual size near the south-east angle yielded a large quantity of bladebones of sheep; the numerous perforations in these showed that they had been used in the manufacture of counters.

Besides the operations in *insulæ* XV. and XVI., a small area was trenched to the south of the parish graveyard, which is within the walls, in view of its immediate inclosure as an additional burying ground. The area is close to the two square temples uncovered in 1890. The foundations of a small house of the corridor type were disclosed, near which was found a lump of worked porphyry.

It will be seen, therefore, that the results of the year's work in no way fall behind those of former years, and that further progress has been made in the systematic excavation of the site of the Roman city, which has now been carried on by the Committee of the Excavation Fund for seven successive seasons.

A special exhibition of the antiquities, &c., found was held at Burlington House during the month of May, and a detailed account of all

[1] *Proc. Roy. Irish Acad.*, vol. iv. 1896, p. 74.

the discoveries has been published by the Society of Antiquaries in 'Archæologia,' lv. pp. 409–430.

It is proposed during the current year to excavate the two *insulæ* (XVI. and XVII.) extending from *insula* III. as far as the south wall.

Although more than half of the area (100 acres) within the walls has now been systematically excavated, and with most important results, the Committee desire to point out that there is still several more years' work to be done before the Romano-British city can be regarded as completely disclosed. They therefore ask to be reappointed, with a further grant of 40*l.* The whole of the grant made in 1896 has been expended.

Functional Activity of Nerve Cells.—Report of the Committee, consisting of Dr. W. H. GASKELL (*Chairman and Secretary*), Mr. H. K. ANDERSON, Professor F. GOTCH, Professor W. D. HALLIBURTON, Professor J. B. HAYCRAFT, Dr. J. N. LANGLEY, Professor J. G. MCKENDRICK, Dr. MANN, Professor BURDON SANDERSON, Professor E. A. SCHÄFER, Professor C. S. SHERRINGTON, and Professor A. WALLER, *appointed to investigate the changes which are associated with the Functional Activity of Nerve Cells and their Peripheral Extensions.*

IT was felt by the Committee that the most hopeful chance of the discovery of the changes which the nerve cell and nerve fibre undergo during activity was by means of investigations in two directions, viz., the changes in histological appearance and in electrical reactions. In furtherance of this object the Committee requested Dr. Mann to investigate the histological appearances in nerve cells after long continued activity; Professor Boyce to investigate the histological changes in nerve cells resulting from the action of drugs; and Mr. Lloyd, the histological changes in nerve fibres under the influence of reagents. For the investigation of the electrical phenomena Professor Waller undertook the electro-physiology of isolated nerve; and Professor Gotch, the investigation of the electrical changes in the spinal cord and roots during activity.

In addition to these two main branches of the inquiry there were numerous other important questions which required an answer; among these the meaning of the medullation of nerve fibres and its relation to their functional activity. The investigation of this problem was entrusted to Mr. Anderson. Again, the cells of the sympathetic nervous system

form a group requiring investigation apart from those of the central nervous system, and it is especially important to know whether one cell and one only is situated on the course of these efferent visceral fibres, as appears to be the case from Langley's experiments with nicotine; Mr. Bunch, therefore, at the suggestion of Professor Schäfer, was entrusted with the investigation of the position of cell stations on the course of sympathetic nerves. Finally the state of activity in a nerve centre owing to the activity of neighbouring or specially correlated nerve centres is a very important question in connection with the functional activity of nerve cells; Professor Sherrington, therefore, was requested to contribute to the report the results of his investigations into the activity of the nervous centres which correlate antagonistic muscles in the limbs.

These different investigations have been carried out by the different observers as far as has been possible in the time, and the results obtained up to the present have been embodied in a series of reports sent in to the Committee. Of these reports it is advisable at present to publish only those in which the investigation has reached a fairly complete stage; this comprises the reports of Dr. W. B. Warrington, of Dr. J. L. Bunch, of Professor Gotch, of Mr. F. Seymour Lloyd, of Professor Sherrington, and of Professor Waller. All these were brought before the Physiological Section at Toronto, and are hereto appended. As regards the researches of Dr. Mann and Mr. Anderson, though considerable progress has been made the results are not yet ready for publication. The Committee are of opinion that what has already been done affords strong evidence of the value of further investigation on the same lines, and therefore request to be reappointed.

APPENDICES.

I. *On the Origin, Course, and Cell-connections of the Viscero-motor Nerves of the Small Intestine.* *By* J. L. Bunch, *M.D.*, *B.Sc.*

[From the Physiological Laboratory, University College, London.]

My investigations into the origin, course, and cell-connections of the viscero-motor nerves of the small intestine have been continued with the aid of a portion of the grant made to the Committee.

About forty experiments in all have been performed, the animals employed being dogs and cats.

The following points have been made out:—

1. In no case has excitation of the vagus either in the neck, after administration of a small dose of atropine, or in the thorax, with or without atropine, caused any contraction, or any increase of the normal rhythmic contractions of the intestine. The action of the vagus is in every instance confined to the stomach. In one case (dog) there appeared to be a diminution in the extent of the movements and a tendency to their inhibition. It is possible that this result may have been produced by a pull exerted upon the small intestine by contraction of the stomach, but it does not seem that this was the cause. It is noteworthy that on *post-mortem* dissection in this case the vagi were found to be distributed mainly to the cœliac plexus, a small proportion only of the nerves passing directly to the stomach.

2. Excitation of either great splanchnic nerve has always caused *diastolic tone* in the intestine of the *cat*, with a tendency to diminution of the extent of the normal rhythmical contractions; these, however, do not, as a rule, cease during the excitation.

3 Excitation of either splanchnic almost always causes *systolic tone* in the intestine of the *dog*. The normal rhythmic contractions are usually continued during the excitations, but their diastole is incomplete. The effect is often followed by diastolic tone. In a few dogs experimented on the effect produced was similar to that in the cat. Varying the rate of excitation produced no difference in the result in either dogs or cats.

4. It is concluded that the vagi contain usually *no* viscero-motor fibres for the small intestine, and that the splanchnics contain both viscero-dilator and viscero-constrictor fibres; the result obtained depending upon the preponderance of one or other kind.

5. The effects of stimulating the anterior nerve roots from the 8th to the 13th post-cervical, or of the cut spinal cord between these roots, are similar to those obtained on stimulating the splanchnic nerves.

6. Intravenous injection of nicotine produces the same effect, but to a much more marked degree, as stimulation of the splanchnics in the same individuals—*i.e.*, in cats always strong diastolic tone; in dogs usually strong systolic tone, but in a few cases diastolic tone.

7. After intravenous injection of about 3 mgr. nicotine in cats, or about 5 to 7 mgr. in small dogs (7 to 10 kilos.) the effects of nerve-root and splanchnic excitation are abolished, but excitation of the mesenteric nerves still produces marked contraction of the intestine.

8. It is concluded, therefore, that there is probably no cell station between the nerve roots and the ganglia of the solar plexus—*i.e.*, that the fibres pass through the ganglia of the sympathetic chain without interruption.

The contrary statement, which I made in a paper presented last year to the Section of Physiology, was based upon the results of two experiments only, and the tracings of these were unsatisfactorily recorded; it has not been confirmed in any of my later experiments.

The nerves to the small intestine appear, therefore, to conform to the general law laid down by Langley regarding viscero-motor fibres, viz.: in having no cell station in the ganglia of the sympathetic chain, and but one cell station between the spinal cord and the peripheral nerves.

II. *Report upon Electromotive Changes in Nerve during Activity. By* Professor FRANCIS GOTCH, *F.R.S., and* G. J. BURCH, *M.A.* (*Oxon.*).

The main object of the present investigation is to ascertain how far the capillary electrometer can be utilised for determining the true relations of the electromotive changes of nerve. Previous observations by many investigators have shown that excitatory electrical changes are propagated along the tissue at a rate closely resembling that of the excitatory process itself—*i.e.*, 30 metres in one second in the sciatic nerve of the frog, at 15° C. The rate of propagation of polarisation electromotive changes is variously stated to be 6 to 12 metres per second in nerve (Bernstein), 30 to 40 metres in polarisable schemata (Hermann), 60 to 120 metres (Borruttau). Since the relationship of the so-called excitatory changes to the polarisation ones must, from the nature of things, be

extremely intimate, the above discrepancies suggest an inquiry as to the efficiency of the methods hitherto employed in the investigation. These have consisted in using repeated electrical currents as the exciting or polarising agencies, and noting the galvanometric effects produced by their summation. The authors were led by some preliminary experiments to infer that the time relations of such multiple effects differ from those of a single change. In order to obtain the necessary record of a single change, a new projection electrometer was constructed and fitted up in connection with a photographic recording arrangement, in a room set apart for the purpose in the physiological laboratory at Oxford.

The new capillary electrometer is of the improved form referred to by one of us (G. J. B.).[1] It is less fragile than the older instruments, and gives better definition with high magnifying power. In sensitiveness and rapidity of action it is superior to those which we have hitherto used. Great difficulties were met with at first owing to the transmission of vibrations through the concrete floor to the pillar, which, although placed in a well sunk 7 feet below the ground, did not furnish a satisfactory base for our very sensitive instrument. These difficulties were finally got rid of by the adoption of a special form of support. Since it was essential to eliminate all vibration errors, a considerable part of the grant allotted to this branch of the research has been devoted to the construction of the stand just referred to.

The experiments are still in progress, but a large number of photographic records have been already made, particularly of polarisation effects and after-effects. These have been obtained in the following polarisable objects: (1) Schema on Hermann's model—*i.e.*, platinum wire core in saturated solution of zinc sulphate; (2) sciatic nerve; (3) sartorius muscle.

1. *Schema.*—The capillary records of the extrapolar polarisation effects produced by a single polarising current give on analysis results which show that the propagation rate is not the same as that obtained from similar experiments carried out by the authors by the repeating rheotome and galvanometric record. The differences between the two sets of results seem to indicate that the rheotonic effects are confused by the presence of a complexus of electrical states.

2. *Nerve.*—The records with nerve exhibit several suggestive characteristics, but this part of the investigation is still in progress, and further reference to it would at present be inadvisable.

3. *Muscle.*—The sartorius muscle was utilised to determine the characters of the capillary records of the two classes of anodal after-effect, the polarisation anodal positivity and the excitatory anodal negativity. These records show, among other facts, that when the excitatory effect is produced it not only swamps the polarisation one, but increases in extent for some little time after the cessation of the polarising current. The records of the excitatory after-effect are further remarkable in showing no indications of oscillation; it would therefore appear that this anodal excitatory change is not a rapid series of states but a single prolonged change. It is thus distinguished from other excitatory changes of similar duration, and cannot be regarded as a response of the same order as that produced by successive stimuli.

[1] G. J. Burch, 'The Electrometer in Theory and Practice,' *The Electrician*, 1896.

III. *The Activity of the Nervous Centres which correlate Antagonistic Muscles in the Limbs. By* Professor C. S. Sherrington, *M.D., F.R.S.*

The recent results of histology in regard to the nervous system have brought with them the view that the physiological continuity between nerve cell and nerve cell does not involve anatomical continuity of the nerve cells. The theory of cellular contact put forward by Forel and Golgi has received a large amount of confirmation from subsequent workers, as Cajal and Kölliker. The place of linkage between nerve cell and nerve cell—the synapsis as it is termed by Professor Foster—is a place where the conduction of nervous impulses is supposed to occur across an intervening substance. This character in the construction of the chain of conductors has given rise to speculation as to possibility of increase or decrease of difficulty for conduction along a given line due to alteration at the gap between adjacent links in the chain.

Various histologists (Renaut, Demoor, Duval, Solvay, Lepine, &c.) assert that the cells of the nervous system possess, to a certain degree, the power of contractility of their processes. Cajal thinks that the neuroglia cells are certainly contractile, probably more so than the nerve cells proper. These authors speak of the expansion and retraction of the branches of the nerve cell. Certain drugs which depress nervous action, such as chloroform and chloral, and certain conditions such as fatigue and sleep, are described as producing or being accompanied by retraction of cell branches in the nerve cells of cortex cerebri, cerebellum, and elsewhere. The retraction of the cell processes is supposed to withdraw the cell from its connections with its neighbours. Interruptions in the chains of conduction for impulses can thus be brought about. There is much that is at any rate simple in this view, and I have attempted to apply a test to it in the case of a certain place of linkage in the spinal cord.

A place of linkage as well known perhaps as any in the central nervous system is that between the afferent fibre of the sensory spinal root and the motor nerve cell of the ventral horn of the spinal cord. I have attempted to examine what happens when the conduction across this link becomes under certain circumstances difficult. It is well known that to judge by their reflex effects afferent nerve fibres are more easily excitable through their end organs than from their cut ends; in other words, reflexes are more easily elicitable from the surfaces of the skin than from the cut ends of cutaneous nerves. The depression of function in this case seems to occur at the synapsis between the spinal end of the afferent fibre and the motor cell of the ventral horn with which it is usually in facile connection. It may be because the severance of the nerve fibre breaks that tonic action (postulated in it as the basis of muscular tonus) which streams along it inwards from its peripheral sensifacient endings. Some peculiar depression of conductivity does seem to be produced between it and the motor horn cells, for the section of the afferent roots to a spinal region renders extremely difficult the obtaining of a reflex from the ascending stem of the root-fibres that have been transected—that is, the connection between the afferent spinal fibre and the motor spinal cell becomes more difficult in consequence of mere severance of the afferent spinal fibre from its own parent cell. The question I

would raise is the following: Is this increase of resistance in the neural conduction due to change in the mutilated afferent nerve cell—*e.g.*, retraction of its cell-processes withdrawing them from their normal apposition against the motor cell—or is it due to change in the motor cell or its processes—*e.g.*, retraction of its dendrites.

The subjoined observations throw, I think, some light on this point.

1. In the monkey and cat after spinal transection at the top of the cervical region flexion of the hind limb can be elicited by stimulation of the skin of the fore limb of the same side—*e.g.*, forepaw. Section of the afferent spinal roots of the hind limb, sets aside this reaction.

2. Similarly, in monkey and cat excitation of the pinna of the ear elicits flexion in the hind limb of the same side of the body, but section of the afferent roots of the nerves of the hind limb sets the reaction aside.

3. When, after transection on the cerebral side of the pons in cat, the condition of extensor rigidity which I have described elsewhere (Proc. R. S. 1896), and termed 'decerebrate rigidity,' has set in, severance of the afferent roots of the nerves of the limbs immediately abolishes this rigidity.

It would appear from these observations, therefore, that the severance of the afferent roots exercises an effect upon the motor nerve cell itself. The effect is such as to cause some change in the motor nerve cell that makes it less accessible not only to the afferent fibres which have been ruptured from their own parent nerve cells, but also to various other afferent fibres.

An objection may be raised against this conclusion on the ground that the mere operation of section of a number of afferent nerve roots involves necessarily the opening of the vertebral canal and the laying bare of a portion of spinal cord, and that that may of itself depress all the functions of all the elements in the spinal cord thus treated. This consideration appears to me a very valid one, and I believe that as a necessity the operative procedure does tend to depress the activities of the cord where it is exposed. But the following observations, I think, show that the depression of conduction cannot be explained in the above cases by the mere influence of the operation.

1. The excitation of the pyramid tract becomes rather more effective after the section of the afferent roots than it was before; that is, the connection between the endings of the pyramid tract fibres and the motor cells of the ventral horn are more easy and patent than previously; that is, an exaltation of function instead of a depression has occurred in this nexus.

2. In the monkey and cat, after spinal transection at the top of the cervical region, although it is easy to obtain flexion of the hind-limb by excitation of the fore-limb of the same side of the body, or of the pinna of the ear of the same side as the hind-limb in which the reflex movement occurs, it is extremely difficult—in my experience often altogether impossible—to obtain from one fore-limb or pinna any movement of the hind limb of the crossed side. After section of the afferent roots of the nerves of a hind-limb it becomes comparatively easy, however, to elicit in the crossed hind-limb movements by excitation of fore-limb and pinna of the same side of the body as that upon which the afferent roots have been severed. But to cut the afferent roots both sides of the spinal cord were in the preliminary operation laid bare.

It seems, therefore, that severance of the afferent fibres to a limb, probably by interrupting a normal continuous conduction along those fibres,

induces a change in the motor nerve cells upon which normally the continuous afferent activity plays in such a way as to render the connection of the motor nerve cell closer with some afferent endings and less close with others.

If increase of resistance to conduction at a synapsis, that is at a place of neural linkage, be due, therefore, to greater separation of nerve cell from nerve cell by retraction of cell branches, I would urge that it occurs in a very marked degree in the dendrite branches of the motor-cell of the ventral horn of the spinal cord.

IV. *On the Action of Reagents upon Isolated Nerve. By* A. D. WALLER, *M.D., F.R.S., and* S. C. M. SOWTON.

A preliminary general account of the experiments we have made during the past year in prosecution [1] of the investigation of the Action of Reagents upon Isolated Nerve, may be given under the following heads :—

§ 1. The influence of acids and alkalies upon currents of action.

§ 2. The influence of acids and alkalies upon electrotonic currents.

§ 3. The influence of carbonic acid and of tetanisation upon electrotonic currents.

§ 4. The influence of alterations of temperature upon electrotonic currents.

§ 5. The action of some anæsthetics and of some alkaloids upon electrotonic currents.

§ 1. *The influence of acids and alkalies upon currents of action.*—Experiments under this head were undertaken at an early stage of our investigation. We soon realised, however, that it would be desirable to postpone the prosecution of this branch of the subject until we should have examined the more fundamental problems concerning the action of acids and alkalies upon electrotonic currents (§ 2). The following summary statement will, however, serve to convey an idea of the scope and tenor of this first group of experiments :—[M=Molecular, N=Normal]

Dilute acid solutions (M/40 to M/10) cause primary augmentation, followed by secondary gradual diminution of the negative variation.

Stronger acid solutions (M/10 to M/5) cause primary diminution and abolition of the negative variation.

Alkaline solutions at all effective strengths (M/50 to M/5) cause primary diminution and abolition.

The effect of an acid solution is not in proportion with its 'avidity.' Approximately equal effects are produced by decinormal acetic, nitric and sulphuric acids.[2] But in the case of some other acids, equinormal solutions give markedly unequal effects. Thus phosphoric acid is less active, and lactic acid is more active than nitric acid ; approximately equal effects being produced by N/5 phosphoric acid, by N/10 nitric acid, and by N/20

[1] An account of previous observations is given in the *Phil. Trans. R.S.* for 1897, and in three papers published in '*Brain*' during 1896 and 1897.

—	—	Strength	Avidity
[2] Acetic acid . .	N/10 or M/10	0·60 per 100	4
Nitric acid . .	N/10 or M/10	0·62 per 100	100
Sulphuric acid .	N/10 or M/20	0·49 per 100	25

lactic acid. Lactic acid is more active than oxalic acid. Caustic potash is more active than caustic soda [and potassium salts are more active than sodium salts]. Approximately equal effects are produced by N/50 potash and by N/15 soda.

§§ 2, 3, and 4. Influence of acids and alkalies, of carbonic acid and of tetanisation, and of temperature, upon electrotonic currents, have formed the chief subject-matter dealt with during the past year.

Short accounts of these investigations have been given by one of us in the Proceedings of the Physiological and of the Royal Societies;[1] and the significance of the results obtained is considered in some detail in the 5th and 6th of a series of 'Lectures on Animal Electricity,' delivered at the Royal Institution (advance proofs of which are presented with this Report, together with copies of the papers mentioned in it). A short paper, published in the Proceedings of the Physiological Society,[2] concerning the action of CO_2 upon muscle, arose from and is connected with our investigation on nerve.

The general lines of our inquiry and its results have been as follows :—

Electrotonic currents are extrapolar effects aroused in living medullated nerve. They are assuredly physiological as well as physical, inasmuch as they are temporarily suppressed by a rise of temperature to a little above 40°, and by the action of anæsthetic vapours.

Normally, in frog's nerve, the A current (*i.e.*, on the side of the anode) considerably exceeds the K current (*i.e.*, on the side of the kathode). The ordinary magnitude of A is, to that of K, as 4 or 5 to 1.

In consequence of a rise of temperature to 40°, the A current is diminished, the K current is increased. In any case the A/K quotient is decreased. In some cases it is reduced below unity, K being greater than A.

The typical effect of moderate acidification is a diminution of the A current and an augmentation of the K current (diminution of A/K).

With acidification below the degree termed 'moderate' the A current may be increased. With acidification above the degree termed 'moderate' the K current may be diminished.

The typical effect of moderate basification is diminution of the K current.

It thus appears that the K current is favoured by acidification, disfavoured by basification, and that alterations of the A current are less uniform and characteristic.

The effect of prolonged *tetanisation* upon the K current is similar to that of acidification, viz. the K current is increased.

The effects of tetanisation upon the A current are less uniform, viz. the A current may be increased, unaltered, or diminished.

There is a close resemblance between the effects of carbonic acid and those of prolonged tetanisation upon the A and K currents. This resemblance (which is commented upon in some detail in the 6th of the 'Lectures on Animal Electricity') may be admitted to rank as confirmatory evidence of the principal conclusion previously arrived at from an examination of currents of action, to the effect that 'the tetanisation of isolated nerve gives rise to a production of CO_2.'

§ 5. *Action of anæsthetics and of alkaloids.*—The scope of inquiry under this head is very extensive, and we are not yet prepared to give a

[1] Action of temperature on electrotonic currents, *Proc. Physiolog. Soc.*, November, 1896; *Proc. R.S.*, December, 1896. Action of acids and alkalies on electrotonic currents, *Proc. Physiolog. Soc.*, January, 1897.

[2] Action of CO_2 on voluntary and on cardiac muscle, *Proc. Physiolog. Soc.*, November, 1896.

detailed and systematic report on any given portion of this extensive field. All that we think desirable at this stage is to offer evidence of the physiological character of the electrotonic currents under our study, by showing that these currents are subject to modification by anæsthetic and other drugs. We have selected for this purpose reagents, the effects of which upon the currents of action were most familiar to us, viz. ether, chloroform, and aconitine.[1]

Electrotonic currents are *temporarily* diminished under the influence of ether (about 50 per cent. vapour in air), *permanently* diminished under the influence of chloroform (about 10 per cent. vapour in air). As regards the expression 'permanently,' it should be remarked that it implies 'during an observation of reasonable length, generally one hour,' for we have more than once observed partial recovery at the end of several hours, and with a new transverse section to the nerve.

[The question of structural disorganisation of nerve by ether and chloroform vapour is dealt with in a separate report (Waller and Lloyd).]

Aconitine hydrochloride in weak solution (1 in 1,000 saline) gives an augmentation of A and K; in stronger solution (1 in 100) it gives a gradual diminution ending in abolition of A and K; in solutions of intermediate strength it gives augmentation followed by diminution. In all the experiments upon which these statements are based the nerve was left to soak for one minute in the test-solution.

V. *Histological Changes in Medullated Nerve after Treatment with the Vapours of Ether and Chloroform, and with* CO_2 *By* A. D. WALLER, *M.D., F.R.S., and* F. SEYMOUR LLOYD.

§ 1. *Introductory Note by* DR. WALLER.

The following observations form part of an investigation of the action of anæsthetic vapours on the electro-mobility of isolated nerve. A brief preliminary account of that investigation was given at the Liverpool meeting of the British Association (1896). The following fuller account deals principally with the practical bearings of the investigation.

The question whether the alterations of electrical response effected by various re-agents depend upon gross and visible alterations of nerve substance presented itself to my mind at the outset of my observations, more especially in connection with the more or less pronounced toxic action of different anæsthetics, and has subsequently been urged upon me from several quarters; together with the question whether the nerves under observation have been really living, and whether their alterations of response in consequence of re-agents has not possibly been due to gross physical disorganisation.

This group of questions may be understood in two senses, one needing only a very brief and clear answer, the other requiring some little reasoning, and probably further microscopic investigation. The answers I am about to give refer only to nerves submitted to volatile re-agents and to three re-agents in solution, viz. KBr, NaBr, and Aconitine.

(*a*) Briefly, there is under the conditions of my observations no visible alteration in structure of the nerve-fibre, but on prolonged exposure to reagents there are more or less distinctly visible alterations. Judged by the only sign available, viz., the negative variation the nerves have been

[1] The effects of ether, chloroform, aconitine, &c., upon currents of action are described in '*Brain*,' 1896, p. 43. Those of the two first-named reagents are also described in the first two 'Lectures on Animal Electricity.'

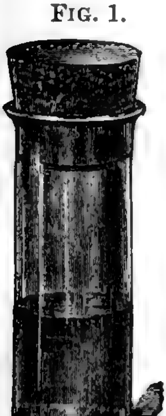
living, and the alteration of response has not been due to visible disorganisation; moreover, where a recovery of response after more or less prolonged suppression was commonly observed or not observed in cases where it was to be expected, for example, after ether, rarely after chloroform, after carbonic acid, not after aconitine. I have attached importance to the fact of *recovery* after *temporary suppression* as being evidence of an effect, which, though no doubt physico-chemical in last resort, may nevertheless be characterised as physiological. And the same remark is applicable to all those cases where there is a temporary augmentation of response.

(*b*) *A priori* it may reasonably be supposed that any alteration of response depends upon some physico-chemical alteration of substance, visible or invisible. The degree to which we are able to extend our knowledge of such material change *de visu* varies, and we may never draw the distinction between organic and functional, or material and immaterial, to correspond with the distinction that may happen to exist for us between visible and invisible. As regards the present investigation, it was sufficient at the outset to be assured of the physiological nature of the observed alterations of response; the limit of visibility of the material alterations upon which these symptoms depended became a matter of secondary interest, that might or might not be of sufficient interest to excite histological investigation. I have been too fully occupied with the purely physiological aspect of the subject to be able to give due time and care to its histological prosecution, and all that I have learned in this direction, in particular the fact that *temporary* alterations are visible in nerve under the temporary influence of anæsthetics, has been obtained from the careful observations of Mr. F. S. Lloyd. From his report it appears that under conditions of experiment considerably more severe than those obtaining in my galvanometric investigation, alterations of structure so slight as hardly to be detected without the closest examination, and in some particulars difficult to distinguish from artifacts, are all that can be observed. The permanent and *a fortiori* the temporary abolitions of electrical response produced in my experiments have therefore not been due to gross disorganisation.

§ 2. *The Microscopic Changes noticed in Isolated Nerve, after treatment with Ether and Chloroform Vapour and with CO_2.* *By* Mr. Lloyd.

The nerves of the frog were invariably employed, especially the sciatic and popliteal nerves, also the dorsal cutaneous nerves. For ordinary work a simple glass thimble was employed, in which a tightly-fitting cork was placed. The tube being half filled with ether or chloroform, as desired, a frog was pithed and a nerve dissected out as quickly and with as little injury as possible. This was lightly stretched on the under surface of the cork, and this replaced in the tube. The nerve thus having been exposed to the concentrated vapour (Et_2O, 50 per cent.; $CHCl_3$, 12 per cent.) for as long or short a time as desired, the cork was withdrawn, and 1 per cent. osmic acid solution substituted for the chloroform or ether, the cork replaced, and the nerve 'fixed' by exposure to the osmic vapour for half to one hour.

Fig. 1.

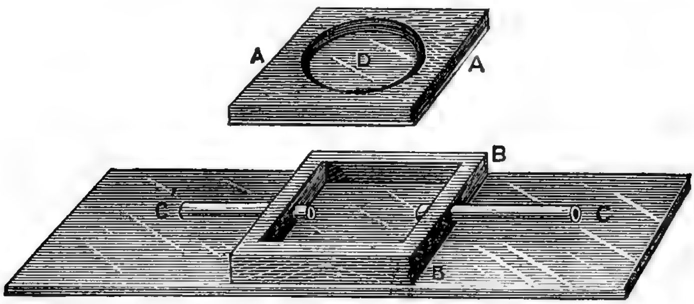


When, however, it was desired to study the microscopic change in the nerve simultaneously with the passage of the required vapour over it, the following apparatus was employed:—

AB represents a cell composed of two parts, AA and BB, and made of wood or glass. The square BB is firmly fixed on to a flat glass basis, and through two of its sides run and are firmly fixed glass tubes CC′, opening into the space enclosed by the four sides of the cell.

The movable top AA has a central circular aperture of about an inch diameter, and to its *under* surface is fixed by some adhesive a large

FIG. 2.

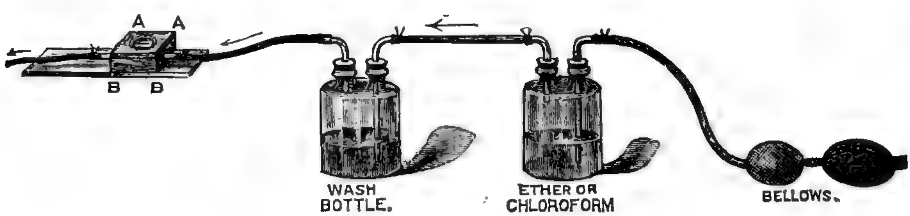


coverslip (see line in diagram), so that when AA is placed on BB and clipped down we have a cell into which the tubes CC open.

The following sketch (fig. 3) will show how it is used in conjunction with the required vapour:—

The nerve is dissected out and lightly stretched on the *under* surface of the cover glass on the cover AA, which is then placed on BB, so that the nerve comes to be inside the cell. One tube C is then connected by rubber tubing with a wash-bottle containing water, the purpose of which is to keep the vapour moist as it passes over the nerve. The wash-bottle is connected with a Woolff's bottle containing ether or chloroform, and

FIG. 3.



fitted with the bellows commonly supplied to freezing microtomes, to vaporise the ether.

In studying the effect of CO_2 a Kipp's apparatus is fitted on in place of the ether bottle and bellows. The cell can be placed under a low or high power of the microscope, and the changes observed simultaneously with the passage of the vapour.

For the observation of the fresh nerve simultaneously with the passage of the vapour, it is convenient to employ nerves as small as possible. The nerves chosen for this purpose were usually the long slender cutaneous filaments seen on opening up the skin of the frog's back. They possess the advantages of being small, and are removable in considerable lengths for observation with a minimum of damage, as they lie comparatively free in the subcutaneous lymph space.

In such a case, the changes in the nerve, as a whole, are readily observable, and moreover it is often possible to find fibres optically isolated at the extreme edge of the bundle, so that individual appearances may be studied.

At other times, however, one of the popliteal nerves was taken, and after placing it in position on the slip, one end was quickly and lightly separated with mounted needles. In nearly every nerve thus treated were visible one or more fibres separated from their fellows for a short distance, rendering individual observation easier, the only drawback being that in this case the nerve must of necessity be more or less injured.

When treating nerves for examination, *after fixation*, by the 'thimble' method described above, obviously the size of the nerve was not a matter of importance, provided that the vapour was given sufficient time to penetrate the bundle.

After medullated nerve fibres have been exposed in either of the above ways to the vapour of ether, or chloroform, or to carbon dioxide gas, for periods varying from 2–5 minutes (according to the size of the nerve chosen) certain *slight* microscopical changes may be observed to have taken place in them. In most cases these changes are but *slight*, and the fibres are not all equally affected. Some may show little or no change from the normal, while the rest show a more or less distinctly visible change.

In observing a preparation, therefore, it is advisable to search it throughout for any of the differences from the normal state, to be subsequently described, for it is not uncommon to only find a few fibres typically affected throughout a whole nerve trunk.

The 'effects' produced by ether vapour and by carbon dioxide are very similar, and usually slight, but the chloroform effect is generally marked in the majority of cases, and is a more thorough change, affecting most of the fibres of a nerve trunk.

These effects are not easily visible in the fresh specimen, but are usually recognisable in tissue subsequently fixed and darkened by osmic vapour, which was found to be the most satisfactory of several fixing agents tried.

The histological changes fall under two headings :—

(*a*) Changes in the appearance and consistency of the medullary sheath ;

(*b*) Changes at the nodes.

Ether Vapour.—The earliest effect is noticeable as soon as twenty seconds after the commencement of administration, a faint granularity appearing in the medullary sheath and slowly increasing for about thirty seconds. It is not an invariable result of the action of ether vapour, and is not always visible in the fresh specimen, but is usually present in the osmic preparation. It must be borne in mind that the myelin tends to become granular after death, and that granularity is often caused by manipulation, thus :—Granularity is invariably present at the cut ends of a nerve.

Another change common to etherised nerve, which is made evident by the blackening action of the osmic acid, is the increased distinctness of the medullary segments or incisures, which appear rather more distinctly than in normal nerve, as light V-shaped markings on a darker ground.

The most distinctive change, however, is at the nodes of Ranvier. (As has been before remarked, the change may be but slight, and does not

necessarily show in every fibre.) At *some* nodes there may be seen a slight approximation of the myelin on each side towards the centre of the node. Besides this, in several fibres, instead of the medullary sheath ending in a rounded extremity at the node, it seems to flow along the axis cylinder from one side to meet the myelin of the opposite side, producing an appearance fitly described by the term 'the waist effect.' In specimens fixed in osmic vapour, and subsequently treated with carmalum, the axis cylinder is seen to traverse the node, and to be apparently there ensheathed by a delicate darkened covering continuous with the medullary sheath on each side of it. This would seem to indicate that there is actual fusion of the myelin of opposite sides across the node. In the smaller fibres the change may be so marked as to almost obliterate the appearance of the node. The 'waist effect' is seen in many fibres usually, the approximation perhaps in but few.

The nodal effect becomes visible after 1–2 minutes of administration, and is usually marked after $2\frac{1}{2}$-3 minutes.

Etherised fibres do not reduce osmic acid so readily as normal fibres—*i.e.*, they do not colour so deeply.

Carbonic acid produces appearances in nerve very similar to etherised nerve, but rarely to such a marked extent. We find much the same appearances in the nodes; granularity may be entirely absent. When present, it is usually coarse; the incisures are even more distinct than in etherised nerve. In one or two cases the appearance has been so marked as to give distinct prominence to the myelin opposite the incisures, the fibre having a knotted appearance comparable to that of a bamboo cane.

The CO_2 effect is usually visible after two minutes' administration.

CO_2 nerves stain readily with osmic vapour. The consistence of the myelin seems to be somewhat altered by action of the CO_2, the medullary sheath tending to break up under manipulation rather more than a normal nerve would under similar treatment.

Chloroform Vapour.—As in etherised nerve, granularity may be observed. It is of a somewhat finer nature than the granulation due to ether, and appears somewhat later.

On examination of a fresh preparation, simultaneously with the administration of the vapour, there is sometimes seen comparatively early a slight approximation of the medullary sheaths at the nodes, followed by a gradual separation commencing shortly after, and reaching its height in about two to two and a half minutes.

On fixing with osmic vapour, the darkening of the myelin shows at the nodes a distinct gap, visible plainly even under the low power. The medulla seems to taper along the axis cylinder for some distance on either side, and terminates in a ragged edge, which seems to suggest fusion with subsequent separation. Other nodes may, however, show no such tapering appearance, the medulla merely being retracted from the node.

Provided that time has been given for the vapour to penetrate, the majority of fibres in a chloroformed nerve show the change, which is usually far more marked and more constant than the change in etherised or 'carbonised' nerve.

The chloroformed nerve does not stain quite so deeply with osmic vapour, as a normal fibre exposed for a similar time.

The consistence of the myelin seems to be altered, it seems to become

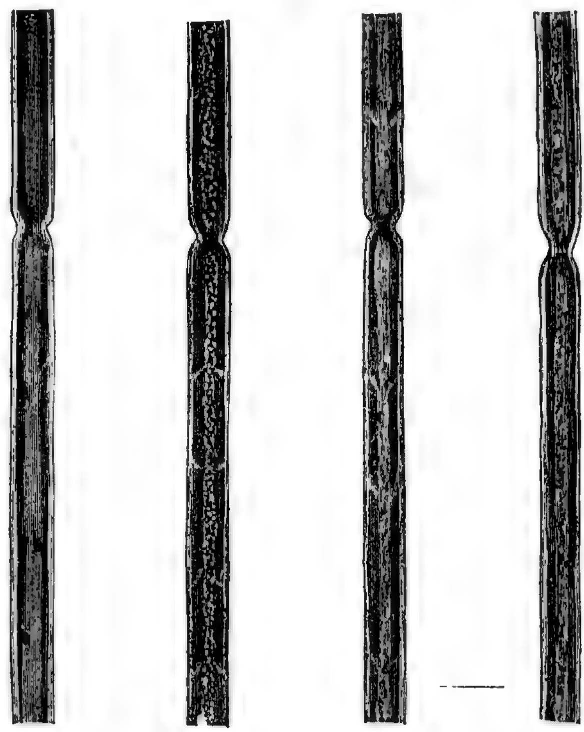
more brittle, tending, even under careful manipulation, to break up into short lengths at irregular intervals.

The incisures are visible, but are usually not nearly so prominent as in etherised or CO_2 nerve. The identification of specimens from a number of mixed slides is generally fairly simple, *provided* that the whole specimen is thoroughly examined, and all the general appearances noted.

If, however, the change is ill-marked, the identification may be a matter of great difficulty. Chloroformed nerve is the easiest to identify, as the change is readily visible, when present, in several fibres.

It is sometimes hard to distinguish between etherised and CO_2 nerve, the appearances being very similar. CO_2 nerve is not usually very granu-

Fig. 4.



Normal. Ether. CO_2. $CHCl_3$.

lar, like etherised nerve, and the incisures are usually much more prominent.

VI. *An Investigation of the Changes in Nerve-cells in Various Pathological Conditions.* *By* W. B. Warrington, *M.D.*, *M.R.C.P.*

Professor Sherrington and Dr. Mott, in the 'Proceedings of the Royal Society,' vol. lvii., have given an account of the influence which the sensory nerves have upon the movements of the limbs. From studying the conditions of the spinal cord in such cases I have been able to find marked changes in the anterior coronal cells.

Thus, the altered functional state of the motor-cells, which occurs when the afferent impulses impinging on them are cut off, is accompanied by a structural change.

The roots cut were those of the cauda equina, and the cells most affected were found in the postero-lateral group.

The typical picture of alteration in the cells is very characteristic.

Using the methylene blue and erythrosin stain, as described by H. Held, the affected cell is somewhat enlarged, is stained red with a small amount of blue chromophilic granules at its periphery. The nucleus remains well marked, and gradually assumes an eccentric position. Finally, the cell is reduced to a hyaline-looking mass, and the nucleus entirely disappears.

Nissl and some others state that changes similar to those described above constantly occur in a cell after division of its axis cylinder. This has been especially investigated in the case of the oculomotorius and faciales nuclei after section of the corresponding nerve-trunk.

In several instances in which I divided the facial nerve at the stylo-mastoid foramen and the oculomotorius nerve intracranially, and made a subsequent examination of the nuclei, I was unable to find changes in the cells corresponding to the descriptions of these observers.

Some of the cells certainly showed alteration in structure, but these were only a very small proportion, while similar cells were seen on the intact side. An account of this investigation will shortly be published in the 'Journal of Physiology.'

Physiological Applications of the Phonograph.—Report by the Committee, consisting of Professor JOHN G. M'KENDRICK (*Chairman*), Professor G. G. MURRAY, Mr. DAVID S. WINGATE, *and* Mr. JOHN S. M'KENDRICK, *on the Physiological Applications of the Phonograph, and on the Form of the Voice-curves made by the Instrument.*[1]

1. THE work of the Committee has, during the past year, been still directed to improving the method by which the curves of the phonograph may be transcribed. The improved Phonograph-Recorder is fully described in the 'Proceedings of the Royal Society of Edinburgh' for session 1896-7, and in the 'Science Lecture' delivered by Dr. M'Kendrick to the Philosophical Society of Glasgow, and published in the 'Proceedings' of that society for session 1896-7.

2. The main results obtained by the Committee during the past year are contained in the following extracts from the lecture above referred to :—

(1) *Physical Constitution of Words.*—First, with reference to speech, I wish to point out that when the record of a *word* is examined it is found to consist of a long series of waves, the number of which depends (1) on the pitch of the vowel constituents in the word, and (2) on the duration of the whole word, or of its syllables individually. There is not for each word a definite wave form, but a vast series of waves, and, even although the greatest care be taken, it is impossible to obtain two records for the same word precisely the same in character. A word is built up of a succession of sounds, all usually of a musical character. Each of these sounds, if taken individually, is represented on the phonograph-record by

[1] See also *Brit. Assoc. Reports* for 1895 and 1896; and *Transactions of the Royal Society of Edinburgh*, 1896.

a greater or less number of waves or vibrations, according to the pitch of the sound and its duration. The pitch, of course, will depend on the number of vibrations per second, or per hundredth of a second, according to the standard we take, but the number of the waves counted depends on the duration of the sound. As it is almost impossible to utter the same sound twice over in exactly the same fraction of a second, or in the same interval of time, the number of waves counted varies much in different records. The rate per unit of time determines the pitch, the number the duration of the sound. In a word, these successive sounds blend into each other, and, in many records, the passage from one pitch to another can be distinctly seen. The speech sounds of a man vary in pitch from 100 to 150 vibrations per second, and the song sounds of a man from 80 to 400 vibrations per second. The sounds that build up a word are chiefly those of the vowels. These give a series of waves representing a variation in pitch according to the character of the vowel sound. In the record of a spoken word the pitch is constantly moving up and down, so the waves are seen in the record to change in length. It is also very difficult to notice where one series of waves ends and where another begins. For example, in the word *Con-stan-ti-nople*, the predominant sounds are those of *o-a-i-o-ill*, and the variation in pitch is observable to the ear if, in *speaking* the word, we allow the sound of the syllables to be prolonged. If we look at the record of the word, we find these variations in pitch indicated by the rate of the waves, or, as the eye may catch this more easily, by the greater or less length of wave, according to the pitch of the sound. The consonantal sounds of the word are breaks, as it were, in the stream of air issuing from the oral cavity, and these breaks (I am not discussing the mechanism at present) produce sounds that have also often the character of vowel sounds. Thus, at the beginning of 'Constantinople,' we have, as will be observed on pronouncing the syllable very slowly, the sound *ŭkkō*. This sound is represented in the record by a series of waves. Then follow the waves of the vowel *o*. Next we have the sound *nn* (driving the air through the nose), also represented by a series of waves. Next the hissing sound *ss*, which has first something in it of the vowel *e* or *i*, and then the *iss-s*. This sound also is shown by a series of waves. Then there is *ta*, which has a double series of waves—(1) those for *it* or *t*, and the next for *a*. This passes into the prolonged vowel *a*, this into *in*, then a long *o*, then a sound like *op*, and, lastly, the sound *ill*, a sort of double-vowel sound. As so many of these sounds have the character of vowels, it is impossible, by an inspection of the record, to say where one set of waves begins and another ends. There are no such breaks corresponding to the consonants; the vibrations of the consonants glide on as smoothly as those of the vowels. The *number* of waves producing a word is sometimes enormous. In 'Constantinople' there may be 500, or 600, or 800 vibrations. A record of the words 'Royal Society of Edinburgh,' spoken with the slowness of ordinary speech, showed over 3,000 vibrations, and I am not sure if they were all counted. This brief illustration gives one an insight into Nature's method of producing speech sounds, and it shows clearly that we can never hope to read such records in the sense of identifying the curve by an inspection of the vibrations. The details are too minute to be of service to us, and we must again fall back on the power the ear possesses of identifying the sounds, and on the use of conventional signs or symbols, such as letters of the alphabet, vowel symbols, consonant symbols, or the symbols of Chinese, which are

monosyllabic roots often meaning very different things according to the inflection of tone, the variations in pitch being used in that language to convey shades of meaning.

(2) *Remarks on Analysis of Curves.*—When human voice sounds are produced in singing, especially when an open vowel sound is sung on a note of definite pitch, the record is much more easily understood. Then we have the waves following each other with great regularity, and the pitch can easily be made out. Still, as has been well pointed out by Dr. R. J. Lloyd, of Liverpool, a gentleman who has devoted much time and learning to this subject, it is impossible by a visual inspection of the vowel curve to recognise its elements. Thus two curves very similar, possibly identical to the eye, may give different sounds to the ear—that is to say, the ear, or ear and brain together, have analytical powers of the finest delicacy. No doubt, by the application of the Fourierian analysis, we may split up the periodic wave into a fundamental of the same period, and a series of waves of varying strength vibrating 2, 3, 4, 5, &c., times faster than the fundamental, and the relative amplitude of each of these may be determined. If all these waves of given amplitude and given phase acted simultaneously on a given particle, the particle would describe the vibration as seen in the original curve. Dr. Lloyd, however, is of opinion that even a Fourierian analysis may not exhaust the contents of a vowel, as it does not take account of inharmonic constituents which may possibly exist. Hermann[1] and Pipping[2] have also been investigating the analysis of vowel tones, and their investigations have revealed many difficulties. Hermann experimented with the ordinary phonograph, and obtained photographs of the movements of the vibrating glass plate. His curves are small, not unlike those seen in Kœnig's flame pictures. In many cases they have sharp points. This, however, may not interfere with analysis. Pipping's curves were not obtained from the phonograph, but from the vibrations of a minute membrane made to represent the drum-head of the ear. His curves show large periodic waves with minute waves on their summits, and they suggest that the large waves may be vibrations due to the membrane itself. Not having seen the apparatus, and as the observations have been made by one well aware of the possibility of this error, I do not venture to do more than suggest this difficulty, especially as I now show you a series of tracings on a glass plate very similar to those in Pipping's figures. These were obtained by singing a vowel into a receiver furnished with a small membrane, to which a recorder was attached. The glass plate (smoked) moved rapidly across in front of the marker. Alongside of these you will see curves obtained directly from the recorder attached to the glass disc of a phonograph. In the second you see waves more like those of Hermann. The larger waves in the tracing, like that of Pipping, are, I believe, due, in my experiment, to the vibrator, and do not represent the glottal vibrations. This conclusion is strengthened by noting the pitch of the sound, as made out by counting, not the larger, but the smaller waves, which corresponds to that of the vowel sound. I therefore think that

[1] Hermann, 'Ueber das Verhalten der Vocale am neuen Edisonschen Phonographen,' *Pflüger's Archiv*, vol. xlvii., 1890; also 'Phonophotographische Untersuchungen,' *op. cit.*, ii. and iii.

[2] Pipping, *Om Klangfärgen hos sjungna Vokaler*. Discussed in Dr. Lloyd's paper on the 'Interpretation of the Phonograms of Vowels.' *Jl. of Anat. and Physiolog.*, 1896.

argument should be based only on records obtained from the phonograph itself, which is furnished with a vibrator that will not record its own periodic vibrations unless the sound be remarkably intense. In ordinary voice production and in ordinary singing the vibrator of the phonograph faithfully records only the pressures falling upon it—no more and no less.

(3) *Recording Intensity of Tones.*—I shall now show you another method of recording, not the individual vibrations of the phonograph, but the variations in intensity of the sounds of the phonograph—the intensities of individual notes and chords. I was led to use this method by becoming acquainted with an instrument devised by Professor Hürthle, of Breslau. He has succeeded in recording the vibrations of the sounds of the heart. I saw that his instrument was very useful, and I adapted it to the particular purpose in hand. Hürthle's instrument is an electro-magnet acting on a metal plate connected with the elastic membrane of a tambour. Another drum is connected with the first by an india-rubber tube. The metal plate of the first tambour is pulled down by the electro-magnet; thus the air is rarefied in the tube and in both tambours, and the lever of the second tambour moves. The next instant the lever flies back. We shall now connect Graham's variable resistance apparatus with the phonograph. As sound waves fall on it a change is produced in the current passing through the electro-magnet; the latter acts on its tambour; a variable pressure is communicated to the other tambour; and if the lever of the latter is brought against a revolving drum, a tracing is obtained. Each note and each chord are recorded, so that you get a mechanical tracing of the variations of intensity.

(4) *Electrical Stimulation of the Fingers by the Rhythm and Varying Intensity of Tone.*—Now this experiment suggested another of a different kind. Suppose I send the current not only through the variable resistance apparatus above the disc of the phonograph, but also through the primary coil of an induction machine. The wires from the secondary coil pass to two platinum plates dipped in weak salt solution. I now set the phonograph going; and when I put my fingers into the beakers containing salt solution, I *feel* the intensity of every note. The variation of intensity, the time, the rhythm, and even the expression of music, are all felt. I shall now place on the mandril of the phonograph a cylinder on which has been recorded another piece of music, which is much quicker. I now feel a series of electrical thrills corresponding to every variation of intensity of sound coming from the phonograph. That method shows that the nerves of the skin can be stimulated by irritations coming to it at the rate of the notes and chords of rapid music. Some of the notes produced by the phonograph do not last longer than the five hundredth or six hundredth part of a second, but they are quite sufficient to stimulate the nerves of the skin, and, as I have pointed out, you can appreciate the variations of intensity. You can *feel* the long-drawn-out notes from the saxhorn or trombone. You feel the *crescendo* and *diminuendo* of rhythmic movement, and you can estimate the duration of the note and chord. You feel even something of the expression of the music. It is rather a pity to say that even expression is mechanical. It is undoubtedly mechanical when you deal with the records of the phonograph. A number of interesting questions of a physiological nature are suggested by this experiment. The skin is not a structure that can analyse tone or distinguish pitch; it cannot tell you the number of vibrations, although there

is a curious approach to it. While it is not by any means accurate, you can distinguish tone of low pitch—very low tones—by a feeling of 'intermission.' Experimenting in this way, you may stimulate by interrupting this circuit at the rate of 30 or 40 or 50 breaks per second, and yet the skin will tell you the individual breaks; but when you get above that number you lose the consciousness of the individual breaks, and you have a more or less continuous sensation. The phonograph does not necessarily give you 50 or 60 *stimuli* to produce a sensation of a tone; you do not require that number. I found that 8 or 10 per second may give you the sensation for a tone of any pitch. In the same way, you may be able to notice a slight difference up to perhaps 50 or 60, but above that the sensation seems continuous. It is not the number of *stimuli* that determines pitch, but the rate at which the *stimuli* affect the sense organ, whether it be ear or skin. Then the question arises, What is it in the skin that is irritated? It is not the corpuscles. They have to do with pressure. There is no organ, so far as we know, for the sense of temperature. You may say that the feeling is muscular. Possibly it may be so; but the effect is most marked when the current is so weak as to make it unlikely that it passes so deep as to reach the muscles.

(5) *Mode of Communication with the Deaf.*—This experiment suggests the possibility of being able to communicate to those who are stone-deaf the feeling, or at all events the rhythm, of music. It is not music, of course, but, if you like to call it so, it is music *on one plane and without colour.* There is no appreciation of pitch, or colour, or of quality, and there is no effort at analysis, an effort which, I believe, has a great deal to do with the pleasurable sensation we derive from music. In this experiment you have the rhythm which enters largely into musical feeling. On Saturday last, through the kindness of Dr. J. Kerr Love, I had the opportunity of experimenting with four patients from the Deaf and Dumb Institution, one of whom had her hearing up till she was eleven years of age, and then she became stone-deaf. This girl had undoubtedly a recollection of music, although she does not now hear any sound. She wrote me a letter, in which she declared that *what she felt was music*, and that it awakened in her mind a conscious something that recalled what music was. The others had no conception of music, but they were able to appreciate the rhythm, and it was interesting to notice how they all, without exception, caught up the rhythm, and bobbed their heads up and down, keeping time with the electrical thrills in their finger-tips.

3. Specimens of the curves may be seen in two plates appended to the Science Lecture of the Philosophical Society above referred to.

4. As the research will in future be prosecuted with the aid of a grant from the Government Grant Fund of the Royal Society, the Committee does not desire to be reappointed.

The Physiological Effects of Peptone and its Precursors when introduced into the Circulation.—Interim Report of a Committee, consisting of Professor E. A. SCHÄFER, *F.R.S.* (*Chairman*), Professor C. S. SHERRINGTON, *F.R.S.*, Professor R. W. BOYCE *and* Professor W. H. THOMPSON (*Secretary*). (*Drawn up by the Secretary.*)

THE present report is to be regarded as a continuation of work the first results of which were communicated by the Secretary of this Committee to the British Association (Section I) at its meeting in Liverpool last year, and afterwards published in the 'Journal of Physiology,' vol. xx., December 1896, p. 455.[1]

The chief conclusions then arrived at concerned the effects of Witte's 'peptone,' and were—(1) That this substance in small doses—below 0·02 grm. per kilo—hastens the coagulation of blood in the dog, while in larger doses retardation is brought about, as other investigators have found. (2) That the well-known fall of blood-pressure produced by this substance when injected into the circulation is due to a peripheral influence upon the neuro-muscular apparatus of the blood-vessels. No influence on the vaso-motor centre was detected. (3) That the vaso-dilating influence of Witte's 'peptone' is not confined to vessels of the splanchnic region, but extends to other vessels also.

This last conclusion was arrived at in an indirect way by observing the effects of Witte's 'peptone' on carotid blood-pressure when injected during excitation of the spinal cord (after complete section), at the level of the third cervical vertebra, the great splanchnics on both sides having been previously divided. Neither time nor circumstances had then permitted the checking of this result by similar injections made during excitation of the sciatics, nor of the observation of plethysmographic variations of limb volume under similar conditions of experiment.

Accordingly, in the work carried out during the past year which has been entrusted to the Secretary, this was the first point to which attention was given. A similar method of observation was then applied in turn to the effects of Witte's 'peptone' on the blood-vessels of the kidney and spleen. This was succeeded by an analysis of the effects (*a*) on blood-coagulation, (*b*) on general blood-pressure and peripheral vaso-motor mechanism, (*c*) on local vascular areas (limb, kidney, spleen) of the following substances—pure peptone, anti-peptone, deutero-albumose, proto-albumose and hetero-albumose. The investigation as regards the latter two substances is as yet too incomplete for publication, nor indeed can it be looked upon as more than preliminary for any of the substances mentioned.

The contents of the present abstract may therefore be summarised as follows:—

I. *Effects of Witte's peptone*—

(*a*) On the blood-vessels of the limb;
(*b*) On the blood-vessels of the kidney;
(*c*) On the blood-vessels of the spleen.

[1] Thompson, 'Contribution to the Physiological Effects of "Peptone" when injected into the Circulation,' *Journ. of Physiology*, vol. xx. December 1896, p. 455.

II. *Effects of pure peptone—*

(*a*) On blood-coagulation ;
(*b*) On blood-pressure and peripheral vaso-motor irritability ;
(*c*) On the blood-vessels of the limb, kidney, and spleen respectively.

III. *Effects of anti-peptone—*

(*a*) On blood-coagulation ;
(*b*) On blood-pressure and vaso-motor irritability.

IV. *Effects of deutero-albumose* dealt with in the same way as have been the effects of pure peptone.

I. *Effects of Witte's Peptone.*

(a) *On the blood-vessels of the limb.*—Plethysmographic observations of the volume of the limb were taken by Mosso's method and compared with a simultaneous tracing of carotid blood-pressure. One or both sciatic nerves were divided and excited by a faradic current. In the earlier experiments an injection of Witte's 'peptone' was made during this excitation, the excitation being also repeated subsequent to the injection. Later it was found more suitable to compare the results of an excitation of definite strength, made after the injection, with the results of an excitation of the same strength made before the injection.

Five experiments were performed, on dogs varying from 7·6 to 10·8 kilos in weight, and employing Witte's peptone in doses of 0·1, 0·15, and 0·2 grm. per kilo of body weight.

The conclusions arrived at by this method support those expressed last year, viz., that Witte's peptone produces a decided dilating effect on limb blood-vessels by lowering the irritability of the peripheral neuro-muscular apparatus, to centrifugal impulses. The effect, however, does not appear to be so pronoûnced on these blood-vessels as upon those of the splanchnic area. A dose of Witte's peptone which is sufficient to completely abolish the effect of vaso-constrictive impulses on abdominal blood-vessels is only able to weaken their effect on blood-vessels of the limb.

(b) *On blood-vessels of the kidney.*—A record of kidney volume was taken by means of Roy's oncometer and oncograph. This was accompanied by a tracing of blood-pressure. A solution of Witte's peptone was injected into the saphenous vein. In the earlier experiments one or both splanchnic nerves, or occasionally the spinal cord, was faradically excited during, and after the injection. This procedure was subsequently modified, and the effects of an excitation of certain strength made before the injection, were compared with the results of the same strength of excitation made after the injection.

Seven experiments were performed. The dogs employed varied in weight from 7·8 to 16·4 kilos, and the dose used in most cases was 0·1 grm. per kilo. In a few experiments double this dose was employed.

The conclusions arrived at from these experiments are similar to those deduced concerning the influence of Witte's peptone on limb blood-vessels. This substance produces a vaso-depressing influence on the blood-vessels of the kidney to a considerable degree, especially in the larger doses employed. The degree to which this influence extends is probably even less than that upon the blood-vessels of the limb, certainly less than that upon other vessels in the abdomen.

(c) *On the blood-vessels of the spleen.*—A spleen curve was taken by

means of Schäfer's spleen box, or by a modification of it, made for the writer of this report, which allowed the organ to be surrounded by a layer of warmed oil, and thus prevented a loss of heat, otherwise liable to occur. This method of recording splenic undulations of volume was found to be much more satisfactory than that of Roy, and fully merits all that Professor Schäfer has elsewhere said about it. Side by side with the spleen curve a tracing of carotid blood-pressure was recorded.

Six experiments were performed, the dogs varying in weight from 7 to 11·7 kilos. In most of the experiments a dose of 0·15 grm. per kilo was employed. In one this was increased to 0·2 grm. The left splanchnic nerve in two of the experiments was divided and excited during the injection. In the remainder either the spinal cord or the splanchnic nerves were excited, before and after the injection, with the same strength of stimulus, and the results compared.

The results showed that the effects of Witte's peptone on the blood-vessels of the spleen were somewhat different from the effect of the same substance on renal and limb blood-vessels.

In the first place it was noted that the spleen volume suffers less of a diminution from the fall of blood-pressure which immediately succeeds an injection of Witte's peptone, and that this fall of the lever was soon replaced by a return to its ordinary level.

Agreeing with this, it was found that the early effects of this substance on the peripheral irritability of splenic blood-vessels was very slight, decidedly less than the same effect on splanchnic vessels generally. Later, however, the contrary result was observed; the splenic blood-vessels seemed then to be more influenced by Witte's peptone than other vessels in the abdominal cavity. This was shown in the later stage by a decided rise of carotid blood-pressure on excitation of the spinal cord, unaccompanied by any effect on spleen volume, while the contrary obtained at an earlier part of the same experiment.

II. *Effects of Pure Peptone.*

(a) *On blood coagulation.*—This was observed in four experiments, the peptone used being prepared according to the directions of Grosjean [1] and supplied to me by Dr. G. Grübler. The dogs used weighed from 8·5 to 18·45 kilos, and in each case a dose of 0·2 grm. per kilo was employed.

In all four cases coagulation was delayed from two to several hours. In one case coagulation occurred at the end of the former period; in two others it had supervened next morning, the experiments having been performed in the afternoon. In the fourth case the onset of coagulation was not observed.

These results agree with those of Grosjean, who found that pure peptone delayed but never wholly destroyed the coagulability of blood. Previous to Grosjean, Pollitzer had obtained inconstant results with ampho-peptone—sometimes no effect, sometimes a variable amount of delay, on the whole his experiments leading to the conclusion that ampho-peptone exerts but slight influence on blood-coagulation.

Whether peptone in smaller doses is capable of producing hastening of coagulation has not as yet been investigated.

[1] Grosjean, 'L'action physiologique de la propeptone et de la peptone,' *Travaux du laboratoire de Léon Fredericq*, tome iv. 1891–92, p. 45.

One other noteworthy effect appeared in the samples of blood drawn in three of the above four experiments—viz., an unusually rapid sinking of the red corpuscles, leaving a perfectly colourless and clear plasma above. Within half-an-hour, plasma to the extent of one-third of the whole blood drawn appeared above the corpuscles, and within one hour this was increased to almost half, after which very little further subsidence was observed. It was in this condition that the blood and plasma coagulated.

In the exceptional case curare had been administered ; the other dogs were not curarised.

(b) *On blood-pressure and vaso-motor irritability.*—Seven experiments, involving a record of blood-pressure, were made with Grosjean's peptone. The dose employed was in all cases 0·2 grm. per kilo, and the weights of the dogs varied from 7·4 to 18·45 kilos.

The general results obtained were the same in all, and showed that pure peptone causes a considerable fall of blood-pressure, and with this a lowering of vaso-muscular irritability to central impulses. The degree and duration of the fall were neither so great nor so lengthened as with corresponding doses of Witte's peptone, nor was the peripheral vaso-motor irritability depressed to the same degree. Thus, after a dose of 0·2 grm. per kilo of pure peptone, blood-pressure had usually returned to its normal level, and with it the response to vaso-motor excitation had likewise, almost, if not fully reappeared.

These results are in accord with those of Grosjean.

(c) *On blood-vessels of the limb, kidney, and spleen respectively.*—In three of the above experiments a record of the volume of each of one of these organs was taken, with the object of noting the effect of peptone on its blood-vessels.

In all three organs it was found that the dose employed produces a distinct lowering of peripheral vaso-motor irritability immediately following the injection. This, however, soon commenced to pass off, and within a short period the response, by a gradual return, assumed its normal proportions.

With regard to any difference shown by the blood-vessels of these organs, little positive can be said based on a single experiment for each. So far, however, as this justifies remark, it would appear that limb blood-vessels are more affected by pure peptone than either renal or splenic.

III. *Effects of Anti-peptone.*

(a) *On blood coagulation.*—This was observed in seven experiments on dogs which varied in weight from 8·7 to 23·95 kilos. The doses employed per kilo were 0·1 grm. in one experiment, 0·2 grm. in four, and 0·3 grm. in two experiments.

In all of these, with one exception, blood coagulation was hastened, in some markedly so. Thus, in one experiment with a dose of 0·2 grm. per kilo, coagulation time was reduced from 9 m. 30 sec. to 2 m. 0 sec. ; in another, with a dose of 0·3 grm. per kilo, from 3 m. 0 sec. to 1 m. 15 sec. ; and in a third, with a dose of 0·1 grm. per kilo, from 5 m. 10 sec. to 2 m. 45 sec.

In the exceptional case, with a dose of 0·3 grm. per kilo., blood-coagulation-time was practically unaltered ; before injection time 3 m. 30 sec., after 3 m. 55 sec..

This result stands in marked contrast to those published last year in

the paper before referred to, concerning Witte's peptone.[1] It was then found that this substance, in doses of 0·1 grm. per kilo, retards coagulation almost invariably, and the same effect was observed to be the rule with doses as low as one-fifth this quantity. Grosjean[2] had also found coagulation to be delayed from one to ten hours by propeptone in doses of 0·1 grm. per kilo. Below 0·02 grm. per kilo a hastening of blood-coagulation was the rule.

The result, however, is corroborated by those of Spiro and Ellinger,[3] published during the course of this research. These observers found a reduction of coagulation-time from eight to four minutes with a dose of 0·6 grm. per kilo. With regard to former investigators, it is to be remarked that Pollitzer[4] did not find that anti-peptone (tryptone) produced any effect on the rapidity of coagulation, agreeing in this with Fano.[5] It is probable that neither of these experimenters used very pure products.

Nor can the hastening effect of Witte's peptone on blood-coagulation, in small doses, be attributed solely to an admixture with anti-peptone, since deutero-albumose in certain doses, as will be shown later, has been found to hasten this process, while in other doses coagulation is markedly retarded.

(b) *On blood-pressure.*—Pollitzer evidently had noted that the effect of anti-peptone (tryptone) on blood-pressure was different from that of albumoses, since he makes an exception of it, stating that its effect is doubtful. In the present research it has been found that anti-peptone in its action on blood-pressure likewise contrasts with other products of proteid digestion. In doses of 0·2 grm. per kilo, after a very transient fall immediately following the injection, blood-pressure returns to a level, as a rule, somewhat higher than before the injection. This was observed also in one of two experiments with doses of 0·3 grm. per kilo each. In the other, the fall lasted somewhat longer, but even here the duration of lowered blood-pressure was very temporary when compared with that of Witte's peptone, minutes as compared with hours.

Spiro and Ellinger[6] also state that they have found essential differences in the effects of this substance, amongst other things, on blood-pressure as contrasted with albumoses. They, however, reserve their results for future publication. It is interesting, as these observers point out, to note the contrast of this substance with that of the albumoses, out of which it arises, in view of the possibility that toxins and anti-toxins are similarly related as to origin.

(c) *On peripheral vaso-motor irritability.*—As might be anticipated, this substance was not found to possess any depressing action on the tone of blood-vessels, either abdominal or general. On the contrary, in many cases a decided increase of irritability was shown.

[1] Thompson, *op. cit.*

[2] Grosjean, 'L'action physiologique de la propeptone et de la peptone,' *Travaux du laboratoire de Léon Fréderiq*, tome iv. 1891–92, p. 45.

[3] Spiro and Ellinger, 'Der Antagonismus gerinnungsbefördender und gerinnungshemmender Stoffe im Blut, &c.' *Hoppe-Seyler's Zeitschrift f. physiologische Chemie*, Bd. xxiii. (1897), Hft. 2, p. 121.

[4] Pollitzer, 'On the Physiological Action of Peptones and Albumoses,' *Journ. of Physiology*, vii. (1886), p. 283.

[5] Fano, 'Das Verhalten des Peptons und Tryptons gegen Blut u. Lymphe,' *Archiv f. Physiol.*, 1881, p. 277.

[6] Spiro and Ellinger, *op. cit.*

Plethysmographic observations on the blood-vessels of the limb, spleen, and kidney in this respect gave concordant results.

IV. *Effects of Deutero-Albumose.*

(a) *On blood coagulation.*—With regard to influence on blood-coagulation, this substance has been found to produce a marked hastening in certain of the experiments, while in others a marked retardation was observed. Nor can the difference be attributed to the amount of dose. So far this has proved irregular.

Thus hastening has been obtained as follows :—

Dose per kilo	Coagulation Time Before		Coagulation Time After	
	M.	S.	M.	S.
0·05 grm.	12	0	3	0
0·20 "	5	0	1	30
0·20 "	4	40	4	5
0·30 "	9	30	1	0

While retardation has been obtained as under :—

Dose per kilo	Coagulation Time Before		Coagulation Time After
	M.	S.	
0·075 grm.	28	0	Several hours
0·1 "	10	0	" "
0·1 "	6	30	" "
0·1 "	7	30	Not after 1 hour
0·2 "	5	50	" "
0·2 "	4	45	Not after three hours. Coagulated next morning.

In the first two of the latter group of experiments there is reason to believe a somewhat overdose of curare had been administered, and also that this substance produces an effect on blood-coagulation. A new supply of this substance had just been obtained which proved to be very active. In these two experiments, with dogs 9·4 and 8·5 kilos respectively, the dose actually given was only two cubic centimetres of a 1-per-cent. solution.

Further experiments are in progress which it is hoped will throw light on the want of uniformity in the effects of the above doses.

(b) *On blood-pressure and vaso-motor irritability.*—Ten experiments were made in blood-pressure and recorded. The dogs varied in weight from 7 to 18·1 kilos, the doses employed being 0·2 grm. per kilo in four experiments, 0·1 grm. in three, 0·3, 0·075, and 0·05 in one experiment each respectively.

The general conclusion arrived at is that this substance produces a more profound and enduring influence on blood-pressure than pure peptone, but less than the same dose of Witte's peptone. Deutero-albumose cannot therefore be regarded as the most potent constituent of Witte's peptone. The experiments here recorded are in agreement with those of other observers on this point.

(c) *On blood-vessels of the limb, kidney, and spleen respectively.*—Observations were made on the effect of deutero-albumose on limb blood-vessels in two experiments, using Mosso's plethysmograph ; on those of the kidney also in two, employing Roy's apparatus ; and on those of the spleen in four, with the modified Schäfer's spleen-box.

The results showed that the vaso-motor mechanism of these organs

is without doubt affected by doses of 0·1 grm. per kilo and upwards. The influence is not very marked, and is probably less than that on splanchnic blood-vessels other than those of the spleen or kidney. Nor did the effect last long; as a rule it had begun to disappear within five minutes, and had almost if not wholly disappeared at the end of half an hour.

In all the foregoing experiments the animals were fully anæsthetised during the whole experiment by means of morphine and atropine administered hypodermically prior to its commencement. Afterwards, when necessary, a mixture of ether and chloroform was employed to maintain the anæsthesia. Curare was given when the spinal cord or nerves other than the splanchnics were excited.

The products employed were furnished to me by Dr. George Grübler, Dresden, and were with few exceptions injected into the external saphenous vein, dissolved in 50 to 60 c.c. of normal saline.

It will be apparent that a considerable amount of work has yet to be done to make even the part of this research now reported upon complete; while a large extent of the research has not as yet been carried sufficiently far for publication owing to want of time. When this is finished it is proposed to publish the whole, including the present part more fully written, with tracings, tables, and protocols of experiments.

Fertilisation in Phæophyceæ.—Interim Report of the Committee, consisting of Prof. J. B. FARMER (*Chairman*), Prof. R. W. PHILLIPS (*Secretary*), Prof. F. O. BOWER, *and* Prof. HARVEY GIBSON.

THE Committee beg to report that the work in contemplation is progressing favourably. From its nature, however, it is best pursued in the summer months. They are not, therefore, in a position to make more than an interim report, and beg to apply for a renewal of the grant for another year.

Preservation of Plants for Exhibition.—Report of the Committee, consisting of Dr. D. H. SCOTT (*Chairman*), Professor BAYLEY BALFOUR, Professor ERRERA, Mr. W. GARDINER, Professor J. R. GREEN, Professor M. C. POTTER, Professor J. W. H. TRAIL, Professor F. E. WEISS, *and* Professor J. B. FARMER (*Secretary*), *appointed to report on the best methods of preserving Vegetable Specimens for Exhibition in Museums.*

THE Committee since presenting their interim report (see B.A. Report, 1896) have continued their inquiries and investigations on the various matters referred to them. The result of these has been largely to confirm the statements already (*loc. cit.*) presented, to which reference may be made for details. Thus for preserving specimens in a liquid medium alcohol on the whole yields the best results, in spite of its decolourising action. Rapid killing and in some cases special methods of bleaching the specimens before immersion in the alcohol are additional precautions which it is desirable to observe.

Experiments have been made to obviate the excessive transparency which the more delicate parts (petals and the like) often assume when preserved in spirit by precipitating salts in the tissues, but they have not hitherto been attended with satisfactory results.

For bulky objects, or for others in which flaccidity occasions no disadvantage, formalin may be used in 5 per cent. to 15 per cent. of the commercial solution. It is cheaper than spirit, and in some cases preserves the colour of the specimen in a more or less natural condition for many months. This retaining of the colour, especially in the case of green tints, is usually more effective if the specimen, rapidly killed by steam or *short* submergence in strong alcohol, be treated for twenty-four hours or longer with a strong bath of copper acetate.

Further details of experiments with other liquids will be found in the appendices of last year's report. Where the specimens are not intended to be handled, drying in sand (*vide* appendix 1, *loc. cit.*) gives admirable results, and in many cases the natural colours are preserved. The extreme fragility of the specimens thus treated constitutes, however, a serious drawback when the objects are intended to be examined and handled by students.

No better methods of mounting specimens for exhibition purposes have been devised than those in use in the Museum of the Royal Botanical Gardens in Edinburgh, an account of which is included in the interim report already referred to.

The Committee desire to express their thanks to those who have kindly given them assistance by communicating such results of their own observation and experience as were connected with the matters now under consideration.

TRANSACTIONS OF THE SECTIONS.

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SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION—Professor A. R. FORSYTH, M.A., D.Sc., F.R.S.

THURSDAY, AUGUST 19.

The President delivered the following Address:—

ONE of the most important events of the past year, connected with the affairs of this Section, has been the reception by the Prime Minister, Lord Salisbury, of a deputation to represent the need for the establishment of a National Physical Laboratory to carry out investigations of certain definite types. Such institutions exist in France and Germany, and have proved of the highest usefulness in a field of work that includes the wide range from pure research to the most direct applications of science to industry. The desire for such an institution in England has long been felt, and as far back as 1891 Professor Oliver Lodge, when presiding over our Section at the Cardiff meeting, argued in its favour. It has frequently been discussed since that date, particularly in 1895, when Sir Douglas Galton dealt with it so ably in his presidential address at Ipswich, and also in a communication to our Section. The subject was then formally referred to a committee of physicists, who, at last year's meeting in Liverpool, presented a report containing a working scheme for developing the Kew Observatory into an institution of the desired character. The recommendations of the report were approved by a unanimous vote of this Section; and were subsequently adopted by the Association. Thereupon a joint committee, representing the various scientific bodies throughout the United Kingdom interested in the matter, was constituted to further the plan: in particular, to urge upon the Government the establishment of such a Laboratory, and, if possible, to obtain from them the funds which are a preliminary necessity for that purpose. It was a deputation from this joint committee which, headed by Lord Lister, waited upon the Prime Minister on February 16 last. His reply to the deputation was manifestly sympathetic with the request; and it is a satisfaction to be able now to say that the Government have appointed a Committee of inquiry, which will also consider whether standardizing and other work, already undertaken partially or wholly at the public cost, can fitly be associated with the new institution.

After having said, by way of preface, thus much upon the chief event of the past year arising partly from our direct action, I wish to turn to the main line of my address, and to ask, for a brief time, your attention and your consideration for the subject of pure mathematics. If, remembering the brilliant address made at the Montreal meeting, you regret that Lord Kelvin is not again now occupying this position: or if, remembering the interest aroused by Professor J. J. Thomson's address last year, you regret that the fascinating tale then opened is not being resumed by some one with imagination enough and knowledge enough to continue it: I can, not unselfishly, share your regret.

It appears, however, from the practice of the Council and the General Committee, to be their policy that mathematicians belonging to the extreme right (if the phrase may be used) shall from time to time be nominated to the presidency of the Section. It is, I think, the case that this Section has always had assigned to it the subjects of Mathematics and Physics. In their development, pure mathematics has continued to be associated with applied mathematics, and applied mathematics with physics. So far as I know, there is no substantial reason why any change should be made, and so far as I have been able to observe, there is a strong consensus of opinion that no change by way of separation need be tried. Wide as is the range of our discussions, distracting as is the occasional variety in the matter of the papers we receive, the complexity of our Section, if in any respect a disadvantage, does not appreciably discount the advantages it otherwise secures. Specialisation in all our subjects has become almost a necessity for progress; but excessive obedience need not be paid to that necessity. On the one hand, there will be danger of imperfect appreciation if a subject is so completely restricted to a few specialists that it is ignored by all but them; and, on the other hand, there will be danger of unsound growth if subject and thinkers alike become isolated, and cease to take an active interest in the methods, the processes, and the results other than those which directly concern them. Accordingly, I think that our group of sciences, which form a continuous range, are better united than divided.

Aristotle declared that it is unbecoming to praise the gods. Observing his canon, I shall say nothing as to the wisdom and the justice of our Executive in sometimes selecting a pure mathematician to preside over this Section. I shall only appeal to your indulgence in accepting the opportunity they have thus given me of speaking more specially about my own subject.

I make this appeal the more earnestly, for two particular reasons. One of these is based upon the conflicting views, popularly held and sometimes summarily expressed, about the subject and those who are addicted to it. It is true that the day has gone by, when it is necessary to give serious consideration to attacks upon mathematical studies, and particularly upon analysis, such as were made by the metaphysician Hamilton: attacks no longer thought worthy of any answer. Feelings of hostility, if ever they were widely held, have given way to other feelings, which in the mildest form suggest toleration and acquiescence, and in the most extreme form suggest solemn respect and distant wonder. By common consent, we are allowed without reproach to pursue our aims; though those aims sometimes attract but little sympathy. It is not so long since, during one of the meetings of the Association, one of the leading English newspapers briefly described a sitting of this Section in the words, 'Saturday morning was devoted to pure mathematics, and so there was nothing of any general interest': still, such toleration is better than undisguised and ill-informed hostility. But the attitude of respect, I might almost say of reverence, is even more trying: we mathematicians are supposed to be of a different mould, to live far up the heights above the driving gales of controversy, breathing a rarer intellectual atmosphere, serene in impenetrable calm. It is difficult for us to maintain the gravity of demeanour proper to such superior persons; and perhaps it is best to confess at once that we are of the earth, earthy, that we have our differences of opinion and of judgment, and that we can even commit the Machiavelian crime of making blunders.

The other of my reasons for claiming your indulgence is of a graver character, and consists in the difficulty of framing general explanations about the subject. The fact is that mathematics do not lend themselves readily to general exposition. Clifford, it is true, could lecture and enchant his audience: and yet even his lectures ranged about the threshold of the temple of mathematical knowledge and made no attempt to reveal the shrines in the sanctuary. The explanation of this initial difficulty is, however, at hand. Our vocabulary is highly technical, perhaps as technical as is that of moral philosophers: and yet even the technicality of a vocabulary can be circumvented by prolixity of statement. But the ideas and the subject-matter in any branch of our study, when even only moderately developed, are so abstract as to demand an almost intolerable prolixity of statement if an attempt is made to popularise them. Moreover, of the many results

obtained, there are few that appeal to an unprofessional sympathy. Adams could discover a new planet by subjecting observations made of the known planets to the most profound calculations; and the world, not over curious about the process, could appreciate the significant result. But such instances are rare; for the most part, our particular results must remain somewhat intangible, somewhat incomprehensible, to those who dwell resolutely and completely outside the range of mathematical knowledge.

What then am I to do? It would be pleasant to me, though it might not prove satisfying to you, to discourse of the present state of one branch or of several branches of mathematics, and particularly to indicate what seem to be lines of possible and probable growth in the future. Instead of pursuing this course, I shall keep my remarks of a general character as far as possible, and shall attempt, not merely to describe briefly some of the relations of pure mathematics to other branches of science, but also to make a bold claim that the unrestricted cultivation of pure mathematics is desirable in itself and for its own sake. Some—I should like to believe many—who are here will concede this claim to the fullest extent and without reservation; but I doubt whether this is so in general. And yet the claim is one which needs to be made before an English-speaking audience. For it is a curious fact that, although the United Kingdom has possessed some of the very greatest of pure mathematicians in the second half of this century, the subject has there received but a scant share of attention as compared with that which it has found in France, in Germany, in Italy, in Sweden and Norway, or in the United States. I am not oblivious of the magnificent contributions to other parts of our science made alike by British leaders and British followers; their fame is known to the world. But apathy rather than attention has been the characteristic feature of our attitude towards pure mathematics; and it seems to me a misfortune, alike for the intellectual activity of the nation and for the progress of the subject, that English thought has had relatively so small an influence upon its vast modern developments.

Now it is not enough for my purpose to be told that the British Association includes all science in its scope, and consequently includes pure mathematics. A statement thus made might be framed in a spirit of mere sufferance; what I wish to secure is a recognition of the subject as one which, being full of life and overflowing with a power of growth, is worthy of the most absorbing devotion. The most cursory examination of the opinions of scientific men leads at once to the conclusion, that there are two views of the subject, both accurate so far as they go, both inadequate whether alone or combined, which to some extent explain if they do not justify what may be called the English attitude in the past. Let me deal with these in succession.

One of these estimates has been framed by what is called the practical man; he regards the subject as a machine which is to provide him with tables, as far as tables can be calculated; and with the simplest formulæ and the most direct rules, whenever tables cannot be calculated. Results, not methods, are his want; it is sufficient for him that an authoritative statement as to a result shall be made; all else is ignored. And for what is beyond, in the shape of work that does nothing to meet his special wants, or of the processes that have led to the results he uses, he cares little or nothing. In fact, he would regard mathematics as a collection of formulæ and an aggregate of processes to grind out numerical results; whatever else there is in it, may be vain and is useless. In his view, it is to be the drudge of the practical sciences.

Now it is undoubtedly an advantage in any case that labour should be saved and time economised; and where this can be done, either by means of calculations made once for all, or by processes that lead to results admitting simple formulation, any mathematician will be glad, particularly if his own work should lead to some such issue. But he should not be expected to consider that his science has thus fulfilled its highest purpose; and perhaps he is not unreasonable if, when he says that such results are but a very small part, and not the most interesting part, of his science, he should claim a higher regard for the whole of it. Indeed, I rather suspect that some change is coming; the practical man himself is changing. The developments in the training for a profession, for example, that of an

engineer, and the demands that arise in the practice of the profession, are such as to force gradually a complete change of view. When I look into the text-books that he uses, it seems to me a necessity that an engineer should now possess a mathematical skill and knowledge in some directions which, not so very long since, could not freely be found among the professional mathematicians themselves. And as this change is gradually effected, perhaps the practical man will gradually change his estimate of the scope of mathematical science.

I pass from the practical men to some of the natural philosophers. Many of them, though certainly far from all of them, expound what they consider proper and economical limits to the development of pure mathematics. Their wisdom gives varied reasons; it speaks in tones of varied appreciation; but there can be no doubt as to its significance and its meaning. Their aim is to make pure mathematics, not indeed the drudge, but the handmaid of the sciences. The demand requires examination, and deserves respectful consideration. There is no question of giving or withholding help in furthering, in every possible fashion and with every possible facility, the progress of natural philosophy; there is no room for difference upon that matter. The difference arises when the opinion is expressed or the advice is tendered that the activity of mathematicians and all their investigations should be consciously limited, and directed solely and supremely, to the assistance and the furtherance of natural philosophy.

One group of physicists, adopting a distinctly aggressive attitude in imposing limits so as to secure prudence in the pursuit of pure mathematics, regard the subject as useful solely for arriving at results connected with one or other of the branches of natural philosophy; they entertain an honest dislike, not merely to investigations that do not lead to such results, but to the desirability of carrying out such investigations; and some of them have used highly flavoured rhetoric in expressing their dislike. It would be easy—but unconvincing—to suggest that, with due modifications in statement, they might find themselves faced with the necessity of defending some of their own researches against attacks as honestly delivered by men absorbed in purely practical work. But such a suggestion is no reply, for it does not in the least touch the question at issue; and I prefer to meet their contention with a direct negative.

By way of illustration let me take a special instance: it is not selected as being easier to confute than any other, but because it was put in the forefront by one of the vigorous advocates of the contention under discussion—a man of the highest scientific distinction in his day. He wrote: 'Measured [by the utility of the power they give] partial differential equations are very useful, and therefore stand very high [in the range of pure mathematics] as far as the second order. They apply to that point in the most important way to the great problems of nature, and are worthy of the most careful study. Beyond that order they apply to nothing.' This last statement, it may be remarked, is inaccurate; for partial differential equations, of an order higher than the second, occur—to give merely a few examples—in investigations as to the action of magnetism on polarised light, in researches on the vibrations of thick plates or of curved bars, in the discussion of such hydrodynamical questions as the motion of a cylinder in fluid or the damping of air-waves owing to viscosity.

Putting this aside, what is more important is the consideration of the partial differential equations of the second order that are found actually to occur in the investigations. Each case as it arises is discussed solely in connection with its particular problem; one or two methods are given, more or less in the form of rules; if these methods fail, the attempt at solution subsides. The result is a collection of isolated processes, about as unsatisfactory a collection as is the chapter labelled Theory of Numbers in many text-books on algebra, when it is supposed to represent that great branch of knowledge. Moreover, this method suffers from the additional disadvantage of suggesting little or no information about equations of higher orders.

But when the equations are considered, not each by itself but as ranged under a whole system, then the investigation of the full theory places these processes in their proper position, gives them a meaning which superficially they do not

exhibit, and indicates the way in which each solution satisfies the general conditions of existence of a solution. For the full theory of partial differential equations of the second order in, say, two independent variables establishes the conditions of existence of a solution, the limitations upon the conditions which make that solution unique, the range of variation within which that solution exists, the modes of obtaining expressions for it when it can be expressed in a finite form, and an expression for the solution when it cannot be expressed in a finite form. Of course, the actual derivation of the solution of particular equations is dependent upon analytical skill, as is always the case in any piece of calculating work; but the general theory indicates the possibilities and the limitations which determine the kind of solution to be expected. But not only does the general theory effect much by way of co-ordinating isolated processes—and, in doing so, lead to new results—but it gives important indications for dealing with equations of higher orders, and it establishes certain theorems about them merely by simple generalisations.

In fact, the special case quoted is one more instance, added to the many instances that have occurred in the past, in which the utilitarian bias in the progress of knowledge is neither the best stimulus nor in the long run the most effective guide towards securing results. It may be—it frequently is—at first the only guide possible, and for a time it continues the best guide, but it does not remain so for ever. It would be superfluous, after Cayley's address in 1883, to show how branches of mathematical physics, thus begun and developed, have added to knowledge in their own direction; they have suggested, they have even created, most fascinating branches of pure mathematics, which, when developed, have sometimes proved of reciprocal advantage to the source from which they sprang. But for proper and useful development they must be free from the restrictions which the sterner group of natural philosophers would lay upon them.

Now I come to another group of natural philosophers who will unreservedly grant my contention thus far; who will yield a ready interest to our aims and our ideas, but who consider that the possibility of applying our results in the domain of physical science should regulate, or at least guide, advance in our work. Some of these entertain this view because they think that possibility of early application is, in the last resource, the real test of useful development; some, because they fear that the profusion of papers annually published and the bewildering specialisation in each branch, are without purpose, and may ultimately lead to isolation or separation of whole sections of mathematics from the general progress of science.

The danger arising from excess of activity seems to me unreal; at any rate there are not signs of it at home at the present day, and I would gladly see more workers at pure mathematics, though not of course at the expense of attention paid to any other branch. But for results that are trivial, for investigations that have no place in organic growth and development, or in illustration and elucidation, surely the natural end is that they soon subside into mere tricks of 'curious pleasure or ingenious pain.' However numerous they may be, they do not possess intrinsic influence sufficient to cause evil consequences, and any attempt at repression will, if successful, inevitably and unwisely repress much more.

More attention must be paid to the suggestion that mathematicians should be guided in their investigations by the possibility of practical issues. That they are so guided to a great extent is manifest from many of the papers written in that spirit; that they cannot accept practical issues as the sole guide would seem sufficiently justified by the consideration that practical issues widen from year to year and cannot be foreseen in the absence of a divining spirit. Moreover, if such a principle were adopted, many an investigation undertaken at the time for its intrinsic interest would be cast on one side unconsidered, because it does not satisfy an external test that really has nothing to do with the case, and may change its form of application from time to time.

To emphasise this opinion that mathematicians would be unwise to accept practical issues as the sole guide or the chief guide in the current of their investigations, it may be sufficient to recall a few instances from history in which the

purely mathematical discovery preceded the practical application and was not an elucidation or an explanation of observed phenomena. The fundamental properties of conic sections were known to the Greeks in the fourth and the third centuries before the Christian era; but they remained unused for a couple of thousand years until Kepler and Newton found in them the solution of the universe. Need I do more than mention the discovery of the planet Neptune by Adams and Leverrier, in which the intricate analysis used had not been elaborated for such particular applications? Again, it was by the use of refined analytical and geometrical reasoning upon the properties of the wave-surface that Sir W. R. Hamilton inferred the existence of conical refraction which, down to the time when he made his inference, had been 'unsupported by any facts observed, and was even opposed to all the analogies derived from experience.'

It may be said that these are time-honoured illustrations, and that objections are not entertained as regards the past, but fears are entertained as regards the present and the future. Very well; let me take one more instance, by choosing a subject in which the purely mathematical interest is deemed supreme, the theory of functions of a complex variable. That at least is a theory in pure mathematics, initiated in that region and developed in that region; it is built up in scores of papers, and its plan certainly has not been, and is not now, dominated or guided by considerations of applicability to natural phenomena. Yet what has turned out to be its relation to practical issues? The investigations of Lagrange and others upon the construction of maps appear as a portion of the general property of conformal representation; which is merely the general geometrical method of regarding functional relations in that theory. Again, the interesting and important investigations upon discontinuous two-dimensional fluid motion in hydrodynamics, made in the last twenty years, can all be, and now are all, I believe, deduced from similar considerations by interpreting functional relations between complex variables. In the dynamics of a rotating heavy body, the only substantial extension of our knowledge made since the time of Lagrange has accrued from associating the general properties of functions with the discussion of the equations of motion. Further, under the title of conjugate functions, the theory has been applied to various questions in electrostatics, particularly in connection with condensers and electrometers. And, lastly, in the domain of physical astronomy, some of the most conspicuous advances made in the last few years have been achieved by introducing into the discussion the ideas, the principles, the methods, and the results of the theory of functions. It is unnecessary to speak in detail of this last matter, for I can refer you to Dr. G. W. Hill's interesting 'Presidential Address to the American Mathematical Society' in 1895; but without doubt the refined and extremely difficult work of Poincaré and others in physical astronomy has been possible only by the use of the most elaborate developments of some pure mathematical subjects, developments which were made without a thought of such applications.

Now it is true that much of the theory of functions is as yet devoid of explicit application to definite physical subjects; it may be that these latest applications exhaust the possibilities in that direction for any immediate future; and it is also true that whole regions of other theories remain similarly unapplied. Opinion and divination as to the future would be as vain as they are unnecessary; but my contention does not need to be supported by speculative hopes or uninformed prophecy.

If in the range of human endeavour after sound knowledge there is one subject that needs to be practical, it surely is Medicine. Yet in the field of Medicine it has been found that branches such as biology and pathology must be studied for themselves and be developed by themselves with the single aim of increasing knowledge; and it is then that they can be best applied to the conduct of living processes. So also in the pursuit of mathematics, the path of practical utility is too narrow and irregular, not always leading far. The witness of history shows that, in the field of natural philosophy, mathematics will furnish more effective assistance if, in its systematic development, its course can freely pass beyond the ever-shifting domain of use and application.

What I have said thus far has dealt with considerations arising from the

outside. I have tried to show that, in order to secure the greatest benefit for those practical or pure sciences which use mathematical results or methods, a deeper source of possible advantage can be obtained by developing the subject independently than by keeping the attention fixed chiefly upon the applications that may be made. Even if no more were said, it might be conceded that the unrestricted study of mathematics would thereby be justified. But there is another side to this discussion, and it is my wish now to speak very briefly from the point of view of the subject itself, regarded as a branch of knowledge worthy of attention in and for itself, steadily growing and full of increasing vitality. Unless some account be taken of this position, an adequate estimate of the subject cannot be framed; in fact, nearly the greater part of it will thus be omitted from consideration. For it is not too much to say that, while many of the most important developments have not been brought into practical application, yet they are as truly real contributions to human knowledge as are the disinterested developments of any other of the branches included in the scope of pure science.

It will readily be conceded for the present purpose that knowledge is good in and by itself, and that the pursuit of pure knowledge is an occupation worthy of the greatest efforts which the human intellect can make. A refusal to concede so much would, in effect, be a condemnation of one of the cherished ideals of our race. But the mere pursuit or the mere assiduous accumulation of knowledge is not the chief object; the chief object is to possess it sifted and rationalised: in fact, organised into truth. To achieve this end, instruments are requisite that may deal with the respective well-defined groups of knowledge; and for one particular group, we use the various sciences. There is no doubt that, in this sense, mathematics is a great instrument; there remains for consideration the decision as to its range and function—are they such as to constitute it an independent science, or do they assign it a position in some other science?

I do not know of any canonical aggregate of tests which a subject should satisfy before it is entitled to a separate establishment as a science; but, in the absence of a recognised aggregate, some important tests can be assigned which are necessary, and may, perhaps, be sufficient. A subject must be concerned with a range of ideas forming a class distinct from all other classes; it must deal with them in such a way that new ideas of the same kind can be associated and assimilated; and it should derive a growing vigour from a growing increase of its range. For its progress, it must possess methods as varied as its range, acquiring and constructing new processes in its growth; and new methods on any grand scale should supersede the older ones, so that increase of ideas and introduction of new principles should lead both to simplification and to increase of working power within the subject. As a sign of its vitality, it must ever be adding to knowledge and producing new results, even though within its own range it propound some questions that have no answer and other questions that for a time defy solution; and results already achieved should be an intrinsic stimulus to further development in the extension of knowledge. Lastly, at least among this list, let me quote Sylvester's words: 'It must unceasingly call forth the faculties of observation and comparison; one of its principal methods must be induction; it must have frequent recourse to experimental trial and verification, and it must afford a boundless scope for the highest efforts of imagination and invention.' I do not add as a test that it must immediately be capable of practical application to something outside its own range, though of course its processes may be also transferable to other subjects, or, in part, derivable from them.

All these tests are satisfied by pure mathematics: it can be claimed without hesitation or exaggeration that they are satisfied with ample generosity. A complete proof of this declaration would force me to trespass long upon your time, and so I propose to illustrate it by references to only two or three branches.

First, I would refer to the general theory of invariants and co-variants. The fundamental object of that theory is the investigation and the classification of all dependent functions which conserve their form unaltered in spite of certain general transformations effected in the functions upon which they depend. Originally it began as the observation of a mere analytical property of a particular expression,

interesting enough in itself, but absolutely isolated. This then suggested the inverse question: What is the general law of existence of such functions if they exist as more than mere casual and isolated occurrences? and how can they all be determined? The answer to these questions led to the construction of the algebraical theory of invariants for linear transformations, and subsequently to the establishment of co-variantive forms in all their classes. Next came the question of determining what is practically the range of their existence: that is, is there a complete finite system of such functions in each particular case? and if there is, how is it composed, when in a form that ought to admit of no further reduction? These questions, indeed, are not yet fully answered.

While all this development of the theory of invariants was made upon these lines, without thought of application to other subjects, it was soon clear that it would modify them greatly. It has invaded the domain of geometry, and has almost re-created the analytical theory; but it has done more than this, for the investigations of Cayley have required a full reconsideration of the very foundations of geometry. It has exercised a profound influence upon the theory of algebraical equations; it has made its way into the theory of differential equations; and the generalisation of its ideas is opening out new regions of the most advanced and profound functional analysis. And so far from its course being completed, its questions fully answered, or its interest extinct, there is no reason to suppose that a term can be assigned to its growth and its influence.

As one reference has already been made to the theory of functions of a complex variable, in regard to some of the ways in which it is providing new methods in applied mathematics, I shall deal with it quite briefly now. The theory was, in effect, founded by Cauchy; but, outside his own investigations, it at first made slow and hesitating progress. At the present day, its fundamental ideas may be said almost to govern most departments of the analysis of continuous quantity. On many of them, it has shed a completely new light; it has educed relations between them before unknown. It may be doubted whether any subject is at the present day so richly endowed with variety of method and fertility of resource; its activity is prodigious, and no less remarkable than its activity is its freshness. All this development and increase of knowledge are due to the fact that we face at once the difficulty which even the schoolboy meets in dealing with quadratic equations, when he obtains 'impossible' roots; instead of taking the wily x as our subject of operation, we take the still wilier $x + y\sqrt{-1}$ for that purpose, and the result is a transfiguration of analysis.

In passing, let me mention one other contribution which this theory has made to knowledge lying somewhat outside our track. During the rigorous revision to which the foundations of the theory have been subjected in its re-establishment by Weierstrass, new ideas as regards number and continuity have been introduced. With him and with others influenced by him, there has thence sprung a new theory of higher arithmetic; and with its growth, much has concurrently been effected in the elucidation of the general notions of number and quantity. I have already pointed out that the foundations of geometry have had to be re-considered on account of results finding their origin in the theory of invariants and co-variants. It thus appears to be the fact that, as with Plato, or Descartes, or Leibnitz, or Kant, the activity of pure mathematics is again lending some assistance to the better comprehension of those notions of time, space, number, quantity, which underlie a philosophical conception of the universe.

The theory of groups furnishes another illustration in the same direction. It was begun as a theory to develop the general laws that govern operations of substitution and transformation of elements in expressions that involve a number of quantities: it soon revolutionised the theory of equations. Wider ideas successively introduced have led to successive extensions of the original foundation, and now it deals with groups of operations of all kinds, finite and infinite, discrete and continuous, with far-reaching and fruitful applications over practically the whole of our domain.

So one subject after another might be considered, all leading to the same conclusion. I might cite the theory of numbers, which has attracted so

many of the keenest intellects among men, and has grown to be one of the most beautiful and wonderful theories among the many in the wide range of pure mathematics; or without entering upon the question whether geometry is a pure or an applied science, I might review its growth alike in its projective, its descriptive, its analytical, and its numerative divisions; or I might trace the influence of the idea of continuity in binding together subjects so diverse as arithmetic, geometry, and functionality. What has been said already may, however, suffice to give some slight indication of the vast and ever-widening extent of pure mathematics. No less than in any other science knowledge gathers force as it grows, and each new step once attained becomes the starting-point for steady advance in further exploration. Mathematics is one of the oldest of the sciences; it is also one of the most active, for its strength is the vigour of perpetual youth.

In conclusion, a few words are due to the personal losses caused since our last meeting. It is but little more than two years since Cayley passed away; his life had been full of work, unhasting and unresting in the almost placid course of his great mental strength. While Cayley was yet alive, one name used to be coupled with his when reference was made to English pure mathematics; the two great men were regarded as England's not unworthy contribution to the exploration of the most abstract of the sciences. These fellow-workers, diverse in temperament, in genius, in method, were bound by a friendship that was ended only by death. And now Sylvester too has gone; full of years and honours; though he lived long, he lived young, and he was happily active until practically the very end. Overflowing with an exuberant vitality alike in thought and work, he preserved through life the somewhat rare faculty of instilling his enthusiasm into others. Among his many great qualities, not the least forcible were his vivid imagination, his eager spirit, and his abundant eloquence. When he spoke and wrote of his investigations, or of the subject to which the greater part of his thinking life had been devoted, he did it with the fascination of conviction; and at times—for instance, in his presidential address to this Section at Exeter in 1869—he became so possessed with his sense of the high mission of mathematics, that his utterances had the lofty note of the prophet and the seer.

One other name must be singled out as claiming the passing tribute of our homage; for, in February last, the illustrious and venerable Weierstrass died. He was unconnected with our Association; but science is wider than our body, and we can recognise and salute a master of marvellous influence and unchallenged eminence.

Thus, even to mention no others, pure mathematics has in a brief period lost three of the very greatest of its pioneers and constructors who have ever lived. We know their genius; and the world of thought, though poorer by their loss, is richer by their work.

> Tho' much is taken, much abides, and tho'
> We are not now that strength which in old days
> Moved earth and heaven; that which we are, we are:
> One equal temper of heroic hearts,
> Made weak by time and fate, but strong in will
> To strive, to seek, to find, and not to yield.

Knowledge cannot halt though her heroes fall: the example of their life-long devotion to her progress, and the memory of their achievements, can inspire us and, if need be, can stimulate us in realising the purpose for which we are banded together as an Association—the advancement of science.

The following Reports and Papers were read:—

1. *Report on Seismological Investigations*
See Reports, p. 129.

2. *Report on Electrolysis and Electro-chemistry.*
See Reports, p. 227.

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3. *On the Unification of Time.* By JOHN A. PATERSON, *M.A.*, *President of the Astronomical and Physical Society of Toronto.*

(1) Time reckoning, as at present conducted, presents curious anomalies. The civil day begins at midnight and ends at the following midnight. The nautical day begins at noon and concludes at noon of the next civil day. The astronomical day begins at noon and ends at the following noon; it is therefore apparent that any given date may extend over or into three different days.

(2) Principally through the efforts of members of the American Society of Civil Engineers and Mr. Sandford Fleming, now Sir Sandford Fleming, an international conference was convened at Washington to consider the whole question of time reform. The representatives of twenty-five nations, as well as the Canadian representative named above, met accordingly in Washington in 1884 at the invitation of the President of the United States, and after a conference extending over a month passed seven resolutions, the first five of which have been practically and generally accepted by the civilised world. The sixth resolution of that remarkable conference was carried unanimously, and is as follows: 'That the conference expresses the hope that as soon as may be practicable the astronomical and nautical days will be arranged everywhere to begin at mean midnight.'

(3) The question of time reform remained in this position until the year 1893, when the Astronomical and Physical Society of Toronto, in co-operation with the Canadian Institute, appointed a joint committee, with Sir Sandford Fleming as chairman, to suggest the best means of ascertaining the views of astronomers throughout the world. This committee accordingly addressed by circular letter the following question to astronomers and other scientific men throughout the world:—

'Is it desirable, all interests considered, that on and after January 1, 1901, the astronomical day should everywhere begin at mean midnight?'

The replies received were in number 171, of which 108 were favourable to the change, and 63 unfavourable. In classifying the replies from astronomers according to the countries from which they were received, 18, including England and the United States, were in favour of the change, and 4 were unfavourable to the change. Classifying the results according to the shipping, the countries favouring the change represent 65 per cent. of the world's marine.

(4) Captain W. Nelson Greenwood, of Lancaster, England, ably assisted the Astronomical and Physical Society of Toronto in obtaining the opinion of shipmasters on the question. The result was that 98 per cent. of those heard from were in favour of the change, representing a total tonnage of 455,810.

(5) An effort towards securing unanimity amongst the nations of the world has been put forth by the Astronomical and Physical Society of Toronto and the Canadian Institute by communications addressed to the Lords Commissioners of the Admiralty through his Excellency the Governor-General. In June 1897 the American Society of Civil Engineers passed a resolution in favour of the reform, and on June 25, 1897, the Royal Society of Canada passed a resolution to request the British Association to co-operate with the Royal Society and other Canadian societies to influence her Majesty's Government to adopt the proposed change.

(6) Hipparchus, the father of astronomy, counted his hours from midnight to midnight. Ptolemy changed this and counted from noon to noon. The present system is a Ptolemaic error. In 1804 La Place proposed to unify astronomical time with civil time, and it was so done until Le Verrier retrograded to the old system. Le Bureau des Longitudes in 1894 reported in favour of the sixth resolution of the Washington Conference.

(7) Very many high authorities can be quoted, such as Sir John Herschel, Cleveland Abbé, Burckhalter, Comstock, J. E. Gore, Hadden, Garrett P. Serviss,

Captain Abney, Lewis Swift, Trouvelot, Dr. Max Wolf, Mendenhall, Mr. Christie, the English Astronomer Royal, and Commodore Franklin, who wrote these words from the United States Naval Observatory, Washington:—'It seems to be eminently proper that the nation which called the conference should be among the first to adopt its recommendations.' The large shipping firm, Lloyds, are much in favour of unification.

(8) If shipping interests, upon which the Empire so much depends, desire unification, the nautical astronomers, even though not a unit, should be asked to accommodate their practice to suit navigators. The nautical astronomer was made for the navigator, and not the navigator for him.

(9) It is therefore hoped that the British Association for the Advancement of Science will lend its aid in bringing this subject before the nations of the world for final consideration.

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4. *Preliminary Note on Photographic Records of Objective Combination Tones. By* A. W. RÜCKER, *F.R.S.*, R. W. FORSYTH, *and* R. SOWTER.

The method of detecting the combination tones by the resonance of a fork was the same as that used by Rücker and Edser ('Phil. Mag.' 39, p. 341, 1895). The interference bands were thrown upon an opaque screen pierced with a narrow slit, behind which was a revolving cylinder covered with photographic paper. When the bands were undisturbed, the traces were parallel straight lines, but these became wavy when the fork was set in vibration. All the principal results obtained by Rücker and Edser were confirmed, and some new experiments were made with König's wave-siren.

FRIDAY, AUGUST 20.

The following Papers were read:—

1. *On the Determination of the Surface Tension of Water, and of certain Dilute Aqueous Solutions by means of the Method of Ripples.*[1] *By* N. ERNEST DORSEY, *Ph.D.*

The method employed is a development of that used by Lord Rayleigh. But by mounting the mirrors on arms rigidly attached to the carriage of a dividing engine, and by viewing the light reflected from the surface of the liquid with a telescope mounted on the carriage and provided with a spider line, I have succeeded in measuring the length of the waves directly with the dividing engine, and with considerable accuracy.

By means of a small lens the horizontal beam of light is rendered parallel before reflection from either mirror. The surface of the liquid was cleaned by means of a flexible brass hoop, as in Lord Rayleigh's work. In reducing the results I have used Lord Kelvin's complete formula.

In a series of twenty-one determinations of the surface tension of water the average was 73·24 dynes per centimetre at 18° C., or 75·98 dynes per centimetre at 0° C.; and the average departure of a single result from the mean of the entire series was only one-fifth of 1 per cent. This value differs from the one found by Lord Rayleigh by about 1 per cent., which is his estimate of the accuracy of his determination, and it agrees with the value found by an entirely different method by M. Sentis in February of this year.

The concentration of the solutions was varied from one-tenth normal to normal, but most of the work was on solutions more dilute than one-half normal, and hence these results are not strictly comparable with those obtained by others who have worked on solutions not so dilute; but, on the whole, the values here found are in accord

[1] Published in the *Physical Review*, vol. v., Nos. 27 and 28, Sept. and Oct. 1897.

with those obtained by others. At these great dilutions the surface tension is a linear function of the concentration in every case studied.

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2. *On a New Method of Determining the Specific Heat of a Liquid in terms of the International Electrical Units.* *By* H. L. CALLENDAR, *M.A., F.R.S., Professor of Physics, and* H. T. BARNES, *M.A.Sc., Demonstrator of Physics, of McGill University, Montreal.*

In view of the probable adoption of the Joule or Watt-second as the absolute unit of heat, it becomes of special interest at the present time to make direct determinations of the natural thermal units in terms of the electrical standards now universally adopted.

In recent years the specific heat of water has been very carefully determined in this manner by Griffiths, and also by Schuster and Gannon. These observers employed the usual calorimetric method, in which a mass of water is heated through a carefully observed range of temperature by means of a measured quantity of electrical energy. Although their methods differed widely in points of detail, their results agreed to within one part in a thousand with each other. But, as Schuster points out, the result so obtained by the electrical method for the specific heat of water differs by one part in 400 from the result obtained by direct mechanical measurements of Joule, Rowland, and Miculescu.

Whatever the cause of this discrepancy, it seemed desirable to repeat the electrical comparison by an entirely different method, to avoid any possible source of constant error which may have remained unsuspected in the calorimetric method as usually practised.

The method which we have adopted consists in passing an electric current through a fine tube, through which a steady current of liquid is flowing. The electrical measurements required are the current and the difference of potential between the ends of the tube. The thermal measurements are the steady difference of temperature and the quantity of liquid flowing in a given time.

The electrical measurements are all made on one potentiometer, preferably a Thomson-Varley slide-box, and present no difficulty, as it is easy to keep the current steady to one part in a thousand for an hour or more, and there is no change in the resistance of the circuit.

The difference of temperature between the inflowing and outflowing liquid, which is also very nearly constant throughout the duration of the experiment, is measured by means of a differential platinum thermometer. The instruments used for this purpose, consisting of a compensated slide-wire resistance box and pair of thermometers, are the same as were exhibited by Prof. Callendar at the conversazione of the Royal Society in 1893, on which occasion the instruments were used for demonstrating the lowering of the melting-point of ice under one atmosphere of pressure. Readings can be taken to the ten-thousandth part of a degree on a rise of temperature of ten degrees.

The current of liquid is kept steady by means of an automatic electromagnetic device, and the quantity flowing in a given time, the interval being also automatically recorded on an electric chronograph, is determined by weighing.

It will be observed that in this method, as compared with that usually employed, since the temperature distribution is exceedingly steady, it is not necessary to determine the thermal capacity of the calorimetric tube with any degree of accuracy. The rate of external loss of heat is also much more steady and more easily determined, and there is no question of lag of the thermometers.

The external loss of heat, which is generally the largest and the most uncertain correction in all calorimetric experiments, can, in the present instance, be made extremely small and regular by the expedient of enclosing the calorimetric tube, &c., in a glass jacket, which is exhausted as perfectly as possible and then hermetically sealed, so that the vacuum cannot suffer further change. The loss can also be measured and eliminated in a very simple manner. If observations are taken with

different values of the electric and liquid currents, the values in each case being adjusted to give the same rise of temperature, it is clear that the temperature distribution, and therefore the external loss of heat, will be very nearly the same. The total loss can be reduced to two or three per cent. of the heat supply on a rise of temperature of 10° C., and the residual differences in any set of observations are but a small fraction of the total loss, and are easily corrected.

We have so far applied the method only to the cases of water and mercury, which present most interest. There is no difficulty, however, in extending the method to the case of other liquids. We have made special arrangements for applying the method to the determination of the variation of the specific heat with temperature, for which purpose it is peculiarly suited, and was, in fact, originally devised. The apparatus may be inspected at the McDonald Physics Building. The essential parts were exhibited at the meeting.

In applying the method to water we have found no difficulty in obtaining steady readings over the range 0° to 50°, and we hope to extend the result to 75°. Special arrangements, which have proved perfectly effective, are made to avoid loss by evaporation.

The results of the observations cannot as yet be published, as they are not sufficiently numerous to merit attention, and still require the application of certain final corrections. The variation to be measured is so small that many of these corrections may considerably alter the result.

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3. *On the Behaviour of Argon in X Ray Tubes. By* H. L. Callendar, *M.A., F.R.S., Professor of Physics, and* N. N. Evans, *M.A.Sc., Lecturer in Chemistry, of McGill University, Montreal.*

In continuation of some experiments made by Professor Callendar in the early part of 1896, the authors have studied the behaviour of argon and some other gases in X Ray tubes of various types. The phenomena presented by a tube filled with carefully dried and purified argon are in many respects peculiar. Under certain conditions the gas appears to be absorbed with extreme rapidity, and with intense sputtering and heating of the kathode. The phenomena appear to depend on the complete elimination of hydrogen from the electrodes, as well as on the degree of vacuum in the tube and the intensity of the current. From experiments on other gases the authors conclude that hydrogen is the most suitable gas for X Ray tubes, and that as a rule the residual gas present is hydrogen. It is possible that the observed absorption of the argon is apparent merely, and corresponds to a sudden increase of the resistance of the tube at a certain stage of the exhaustion, and not to an actual disappearance of the gas.

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4. *On the Fuel Supply and the Air Supply of the Earth. By* Lord Kelvin, *F.R.S.*

All known fuel on the earth is probably residue of ancient vegetation. One ton average fuel takes three tons oxygen to burn it, and therefore its vegetable origin, decomposing carbonic acid and water by power of sunlight, gave three tons oxygen to our atmosphere. Every square metre of earth's surface bears ten tons of air, of which two tons is oxygen. The whole surface is 126 thousand millions of acres, or 510 million millions of square metres. Hence there is not more than 340 million million tons of fuel on the earth, and this is probably the exact amount, because probably all the oxygen in our atmosphere came from primeval vegetation.

The surely available coal supply of England and Scotland was estimated by the Coal Supply Commission of 1871, which included Sir Roderick Murchison and Sir Andrew Ramsay among its members, as being 146 thousand million tons. This is approximately six-tenths of a ton per square metre of area of Great Britain. To burn it all would take one and eight-tenths of a ton of oxygen, or within two-

tenths of a ton of the whole oxygen of the atmosphere resting on Great Britain. The Commission estimated fifty-six thousand million tons more of coal as probably existing at present in lower and less easily accessible strata. It may therefore be considered as almost quite certain that Great Britain could not burn all its own coal with its own air, and therefore that the coal of Britain is considerably in excess of fuel supply of rest of world reckoned per equal areas, whether of land or sea.

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5. *A Canadian and Imperial Hydrographic Survey. By* ALEXANDER JOHNSON, *M.A., LL.D., Professor of Mathematics, Vice-Principal, McGill University.*

In 1884, at the Montreal meeting of the Association, a paper was submitted to Section A by the present writer, in consequence of which a Committee was appointed for the 'Promotion of Tidal Observations in Canada.' The writer was made Secretary, and subsequently Chairman. This Committee, supported by the Royal Society of Canada and by those specially interested in navigation, succeeded, after many delays, in getting the Canadian Government, in 1890, to make a grant for tidal observations, which were to include, not only the rise and fall of tide, but also the tidal currents. The grant was continued from that time until the present year, when it was reduced, so that the survey of the currents could not be continued this summer, although an investigation of the utmost importance for the navigation of the St. Lawrence, more especially when the 'Fast Atlantic Line' is going to be established. Possibly the entire grant is imperilled.

It is believed that this reduction would probably not have taken place had there been in existence a fully organised Hydrographic Survey for Canada to advise the Government. The Royal Society of Canada had some time ago recommended the creation of such a department, and at its recent meeting in Halifax appointed a deputation to present its views to the Government.

The work of such a department can probably be most effectively carried out with the co-operation of the Admiralty.

The object of the present communication is to seek the advice and aid of the British Association in inducing the Imperial and Canadian Governments to act together in making the necessary arrangements, which, if found satisfactory, might possibly be extended to other colonies, and thus the basis of an 'Imperial Hydrographic Survey' might be laid.

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6. *On the Specific Heat of Superheated Steam.*
By Professor J. A. EWING, *F.R.S., and* Professor STANLEY DUNKERLEY.

The authors measure the amount of heat required to heat steam above its temperature of saturation by allowing dry saturated steam to pass through a porous plug and observing its temperature and pressure before and immediately after the passage. The total heat of the steam before passing the plug is known from the experiments of Regnault, and this is equal to the total heat of saturated steam at the pressure beyond the plug *plus* the amount of heat required to heat steam at that (constant) pressure from the temperature of saturation up to the observed temperature. Hence the second of these two quantities of heat is found. In preliminary experiments the pressure beyond the plug was atmospheric, and the observations consequently related to the superheating of steam under atmospheric pressure. The experiments have not yet been carried far enough to determine with certainty what happens during the very first stages of superheating, but it appears from the preliminary observations that the mean specific heat for the first ten degrees of superheating is less than the mean specific heat for larger amounts of superheating. At higher temperatures of superheating under this pressure the specific heat approximates to the value 0·48, as determined in the direct measure-

ments of Regnault. It is the authors' intention to continue the experiments, and extend the method to higher temperatures and to higher pressures in order to obtain results that will be applicable to present engineering practice.

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7. *New Varieties of Kathode Rays.* *By* SILVANUS P. THOMPSON, *F.R.S.*

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8. *On the Spectra of Oxygen, Sulphur, and Selenium.*
By C. RUNGE *and* F. PASCHEN.

The spectrum of oxygen when an electric current is passed through a vacuum tube containing that body, and when no spark gap or Leyden jar is interposed in the circuit, closely resembles the spectrum of helium. It consists of six 'series' of lines forming two sets of three each. Each set of lines is very similar to the whole spectrum of any one of the alkali metals. There is therefore no more spectroscopic evidence in favour of the supposition that helium consists of two elements than there is for oxygen. Under similar circumstances sulphur and selenium give out each a spectrum closely resembling one of the sets of three series. But we are not sure whether the other set does not find its analogy also. The three sets in the spectra of oxygen, sulphur, and selenium, which are analogous to one another, all consist of triplets of a very marked character, the difference of wave numbers increasing as we pass from oxygen to sulphur and from sulphur to selenium in roughly approximate proportion to the squares of their atomic weights. The spectrum of each of the three bodies, as a whole, is situated further to the side of the smaller wave numbers—that is to say, it consists of slower oscillations the greater the atomic weight of the body.[1]

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9. *The Influence of Pressure on Spectral Lines.*
By J. LARMOR, *F.R.S.*

A definite picture of the relations of the æther and matter is obtained by assuming the material molecule to be made up of electrons or intrinsic strain-centres in the æther.[2] A system of electrons describing steady orbits round each other, after the manner of the bodies of a solar or stellar system, would represent a molecule; any disturbance of this steady motion would induce radiation across the æther, which would last until it had reduced the motion again to a state of steadiness. The natural configuration of a molecule would, however, be the unique one of minimum energy corresponding to its intrinsic constant rotational momenta, for the influence of radiation would set towards this configuration, and would not allow much departure from it.

The wave-lengths of luminous radiation are about 10^3 times the linear dimensions of the molecules; thus the intrinsic luminous periods are those of rather slow periodic inequalities (in the sense of physical astronomy) in the orbital motions. This circumstance allows us to roughly appreciate the order of magnitude of the influence of the surrounding medium on these free periods. On account of their slowness the æthereal oscillations which are governed by the inequalities of the orbits of the electrons are sensible over the space occupied by some thousands of molecules each way, and this number is so great as to tempt us to form an idea of the influence of these imbedded molecules by considering them to form a continuous medium. If now the molecules were vibrating in a homogeneous medium, say, surrounded by simple æther, the free periods would vary inversely as the square root of the elasticity of this ambient medium, provided we could assume that change of the medium did not involve change of type of the steady intramolecular orbits. This latter circumstance, however, will also operate to alter the periods,

[1] See Wiedemann, *Annalen*, 61, p. 641, 1897.
[2] Cf. *Phil. Trans.*, 1895, pp. 695–743.

and will be of the same order of importance as the other. Now the effective elasticity of the gaseous medium surrounding the vibrating molecule, when thus treated as continuous, varies inversely as its dielectric constant. We should thus expect on the above hypothesis that increase of pressure would lower the free periods roughly in the same ratio as it raises the square root of the dielectric constant. To reduce to figures: a shift of $\frac{1}{40}$ of the distance between the D lines would correspond to $\delta\lambda/\lambda = \frac{1}{4}.10^{-4}$, while the dielectric constant of air at 0° C. and atmospheric pressure is 1·0006. Thus this shift towards the less refrangible end would indicate a change of density of the surrounding air of the order of that due to a pressure of $\frac{1}{10}$ of an atmosphere at 0° C.

This would make the effect about 10^2 times too large for the observations: thus the main seat of the æther strain maintaining the vibrations of the molecule is the free æther immediately surrounding it, and the loss of stiffness due to the other molecules which are some way off diminishes the free periods only about 10^{-2} times as much as if it were averaged right up to the vibrator. With similarly constituted lines, it is the relative shift $\delta\lambda/\lambda$ that is proportional to the change of density of the medium.

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10. *Changes in the Wave-frequencies of the Lines of Emission Spectra of Elements.* *By* W. J. HUMPHREYS.

For more than two years the best spectroscopic equipment of the Johns Hopkins University has been devoted chiefly to the study of changes in the wave-frequencies of the lines of emission spectra. It was found, soon after the investigation was begun, that a change in atmospheric pressure about an electric arc, in which a substance was being volatilised, caused a change in the wave-frequencies of the spectral lines so produced. In studying this phenomenon a concave Rowland grating of the largest size was used, and the electric arc was formed in a closed cylinder provided with a quartz window, the pressure being obtained by pumping air into this cylinder to any extent desired—usually till the gauge registered from six to twelve atmospheres.

Besides a number of eye observations several hundred photographs were taken, and a large number of lines carefully measured. In fact, the spectrum of almost every known metallic element has been examined at various pressures.

No lines were found to shift more than a fraction (usually less than the tenth) of an Ångström unit, but the shifts are of such regularity that as the work progressed several interesting relations between the shifts of the lines, the conditions under which the lines are produced, and the elements producing them became evident. Some of these relations (given below) may be more or less accidental, while doubtless others of as great importance have been overlooked. However the labour of the investigation was spent in determining the facts in regard to the lines examined, and not in hunting after empirical relations.

It is impossible, of course, in a mere abstract to enter into details of any description, and I shall therefore confine myself to the following summary of results. These are:—

1. Increase in pressure around the arc causes all isolated lines to shift towards the red end of the spectrum.

This is entirely independent of the manner of the lines spreading out, and is the same for a line when reversed as when it is fine and sharp. Even those lines which, like the sodium lines λ3302 and λ3303, spread to the violet give reversals that shift to the red.

2. The shift is directly proportional to the increase of pressure about the arc.

3. It does not depend upon the partial pressure of the gas or vapour producing the lines, but upon the total pressure. In other words, it is not affected by quantity of material in the arc.

4. The shift of the lines seems to be nearly or quite independent of temperature.

5. The lines of bands, at least those of cyanogen and of aluminium oxide, are not appreciably shifted.

6. The shifts of similar lines of a given element are to each other as the wave-lengths of the lines themselves.

7. Different series of lines (as described by Kayser and Runge) of a given element are shifted to different extents. When reduced to the same wave-length these shifts are to each other approximately as one to two to four for the principal, first, and second subordinate series respectively.

8. Similar lines of an element, though not belonging to a recognised series, are shifted equally (when reduced to the same wave-length), but to a different extent than are those unlike them.

9. Shifts of similar lines of different substances are to each other, in most cases, inversely as the absolute temperatures of the melting points of the substances that produce them.

10. The shifts of similar lines of different elements are to each other approximately as the products of the coefficients of linear expansion and cube roots of the atomic volumes of the respective elements (in the solid state) to which they are due.

11. Elements belonging to the same half of a Mendelejeff group give lines which shift proportionately to the cube roots of their respective atomic weights.

12. The lines produced by those substances which, in the solid form, have the greatest coefficients of linear expansion have the greatest shifts. The converse is also true.

13. The shift of similar lines is a periodic function of atomic weight, and consequently may be compared with any other property of the elements which itself is a periodic function of their atomic weights.

A portion of this investigation was conducted jointly with Dr. J. F. Mohler, and the whole of it under the direction of Professor Rowland and Dr. Ames, Directors of the Physical Laboratory of the Johns Hopkins University.

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11. *An Experiment with a Bundle of Glass Plates.* *By* Professor Silvanus P. Thompson, *F.R.S.*

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12. *A Tangent Galvanometer.* *By* Professor Silvanus P. Thompson, *F.R.S.*

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13. *On the Constitution of the Electric Spark.* *By* Arthur Schuster, *F.R.S.*

If the spark of a Leyden jar discharge is examined by means of a spectroscope it is found that the metallic lines are not confined to the immediate neighbourhood of the poles, but are sometimes seen several millimetres away from the electrodes, from which they must have been projected with considerable velocity.

How to measure the velocity of projection has always seemed to me to be a problem of interest. Apart from the information a knowledge of that velocity might give us concerning the mechanism of the spark discharge, it is not impossible that light might be thrown on some important points in spectrum analysis which are at present under discussion. Thus, for instance, if the speed with which a molecule is pushed forward into the centre of the spark depends on molecular weight, we might hope to separate from each other those lines of a spectrum which belong to different molecular combinations.

At various intervals during a number of years I had made unsuccessful attempts to deal with this problem, when I became acquainted with the elegant

method used by Professor Dixon in some of his recent experiments, in which a photograph is taken on a film fixed to the rim of a rapidly revolving wheel.

On trial it was found that the molecular speed is sufficiently small to be measured by this method.

The experiments were conducted by M. Gustav Hemsalech, to whose care and skill their success is largely due. Without entering into a detailed description of the apparatus it will be sufficient to say that the photographs exhibited to the Section were taken on a film moving with a linear speed of about 80 $\frac{\text{metres}}{\text{second}}$ in a direction at right angles to the slit of the spectroscope. While the air lines appear perfectly straight, though slightly broadened, the metallic lines are inclined and curved. The spark was taken from five Leyden jars, charged by means of a Voss machine, the distance between the electrodes being about 1 cm. A single spark produces a good spectrum, reaching approximately from $\lambda = 5000$ to $\lambda = 4000$.

Photograph I. is that of a spark taken between zinc poles on a stationary film. It serves to show the sharpness of the lines in a spectrum of zinc and air.

Photograph II. was taken immediately after *I.*, but on the moving film; the curvature of the zinc lines shows that the velocity of the molecules is gradually diminishing away from the poles. Close to them it must be very large. The average velocity up to a distance of one millimetre from the electrode is 2000 $\frac{\text{metres}}{\text{second}}$, and at a distance of four millimetres. This is reduced to something like 400.

Photograph III. The upper pole is still zinc, while in the lower pole a piece of metallic bismuth has been substituted. The three most refrangible ones, that at 4259, being the strongest of them, are decidedly more inclined than the zinc lines, while the line 4560 seems almost straight.

Photograph IV. The poles are again zinc and bismuth, but both poles are moistened with a solution of calcium chloride. The photograph reveals the curious fact that Bi 4259, which was very much curved on *III.*, is now much less so. The comparison with Ca 4226 clearly shows the greater inclination of the calcium line. The latter is more inclined than H and K, and if the difference in molecular velocity is due to differences in molecular weight, this would show that H and K belong to a simpler molecule than 4226.

I do not desire to express any opinion respecting the bearing of these experiments on the hypothesis of dissociation, as some of the photographs reveal rather puzzling appearances which must first be cleared up before any certain conclusions can be drawn.

All the photographs show clearly that the luminosity of the metallic particles is a phenomenon subsequent to the discharge proper which takes place through the air. Even close to the pole the brightest parts of the metal lines are displaced, as compared with the brightest part of the air line. If we could fix our attention on a point halfway between two zinc poles we should see this point flash out twice with a dark interval between the luminosities. At the moment the spark passes, the air becomes luminous, and remains so for a period, which, in our experiments, did not exceed $\frac{1}{200000}$ of a second. After an interval of about $\frac{1}{50000}$ part the zinc molecules arrive at the centre of the spark, and remain luminescent for an appreciable time with diminishing intensity. The numbers are of course approximate, as they must depend on the intensity of the spark.

The photographs submitted had been enlarged about five times, but a few prints taken from the original negatives were also shown.

The experiments were made with comparatively rough appliances, and the optical arrangement was defective in several respects. A more perfect apparatus is in course of construction, and I hope to continue the research in conjunction with M. Hemsalech. The preliminary results which have been described are sufficient to show that the method is likely to furnish interesting information.

14. *A Reduction of Rowland's Value of the Mechanical Equivalent of Heat to the Paris Hydrogen Scale. By* WM. S. DAY, *Ph.D., Columbia University.*

The measurement of the mechanical equivalent of heat made by Professor Henry A. Rowland at the Johns Hopkins University in Baltimore in 1877–79 [1] is probably the best one that has thus far been made in which the heat was produced by the expenditure of mechanical energy. Later careful determinations by electrical methods, however, give results higher by about one part in four hundred. The discrepancy may be due to errors in the measurement of energy or in the measurement of temperature. Rowland's measurement of temperature was based on comparisons made between an air thermometer and three Baudin mercurial thermometers, by which he reduced his measurements to the absolute thermo-dynamic scale. It was the object of the investigation described here to compare these thermometers with the hydrogen scale of the International Bureau of Weights and Measures at Sèvres, near Paris, and make a recalculation of his value of the mechanical equivalent accordingly.

For this purpose three Tonnelot thermometers, which had been carefully studied at the International Bureau, and compared with their standards at several points of the scale, were obtained and compared with the three principal thermometers used by Rowland in his experiment. These comparisons were made in a horizontal comparison tank designed and constructed for the purpose. Rowland's thermometers were originally compared and used in a vertical position, but the horizontal position was chosen for these comparisons for several reasons of a practical nature. The pressure coefficients of the thermometers were measured, however, and a pressure correction was applied to each reading. In all other respects the attempt was made to use Rowland's thermometers in the way in which he used them.

The zeros of the Tonnelot thermometers were determined immediately after each measurement at any given temperature. The ice used in taking the zeros was artificial ice, and was very pure. The thermometers were always read in taking zeros, and in the comparison tank, by means of a reading telescope and micrometer.

From the comparisons made, corrections were obtained for each of Rowland's thermometers, which, when applied to their indications reduced to the absolute scale by the tables given in his paper on the mechanical equivalent, would make them agree with the Paris hydrogen scale. From these corrections, Rowland's value of the mechanical equivalent was recalculated, taking into account each individual experiment, the thermometers used in it, and the number of observations made with each thermometer. The original values and the corrected values found in this way are compared at several temperatures in the following table. The numbers are in the C.G.S. system and hydrogen scale, and represent the number of ergs required to raise the temperature of one gram of water one degree on the hydrogen scale.

Temperature	Old Value	Corrected	Griffiths	Schuster and Gannon[2]
6°	4209×10^4	4203×10^4	—	—
10	4200×10^4	4196×10^4	—	—
15	4189×10^4	4188×10^4	4200×10^4	—
20	4179×10^4	4181×10^4	4193×10^4	4191×10^4
25	4173×10^4	4176×10^4	4187×10^4	—
30	4171×10^4	4174×10^4	—	—
35	4173×10^4	4175×10^4	—	—

These values give the same variation for the specific heat of water between 15° and 25° as Griffiths' experiment does; since if we divide Rowland's corrected values

[1] *Proc. Am. Acad.* (15), 1879, p. 75.
[2] *Phil. Trans.*, 1895, 186A, p. 458.

at 15°, 20°, and 25°, by his value at 15°, and do the same for Griffiths' values, we get in each case as quotients the numbers 1, 0·998, 0·997.[1]

This seems to indicate that the discrepancy between Rowland's results and those obtained electrically is not one of thermometry, but an error in the measurement of energy, possibly in the standards of electrical resistance, or of electromotive force.

[A note concerning these comparisons appeared in the Johns Hopkins University Circular for June 1897. The corrected values for the mechanical equivalent given in it differ a little from those given above, owing to a slight error in the method used at first in reducing the comparisons.]

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15. *A Comparison of Rowland's Mercury Thermometer with a Griffiths' Platinum Thermometer. By* F. MALLORY *and* C. W. WAIDNER.

SATURDAY, AUGUST 21.

The Section did not meet.

MONDAY, AUGUST 23.

The Section was divided into two Departments.

The following Reports and Papers were read:—

DEPARTMENT I.—MATHEMATICS AND PHYSICS.

1. *Report on Tables of certain Mathematical Functions.*
See Reports, p. 127.

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2. *On the Solution of the Cubic Equation. By* ALEXANDER MACFARLANE.

In a paper recently contributed to the American Institute of Electrical Engineers[2] the author showed that the two roots of a quadratic equation may always be viewed as a pair of conjugate complex quantities, either circular or hyperbolic. The real roots can be viewed as hyperbolic complex quantities. In this paper it is shown how the two binomials which occur in Cardan's formula may be treated as complex quantities, either circular or hyperbolic; and a general method is given for deducing all the roots of the cubic, whether the formula is reducible or apparently irreducible. The trigonometrical meaning is shown of the two non-real roots in the reducible case: they involve the cosine of an angle, which is partly circular, partly hyperbolic.

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3. *The Historical Development of the Abelian Functions. By* Dr. HARRIS HANCOCK.—See Reports, p. 246.

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4. *On a Notation in Vector Analysis. By* Professor O. HENRICI, *F.R.S.*

The notations in use to denote the different products of vectors are not sufficiently expressive, and not convenient in use. The author therefore proposes

[1] Griffiths, *Phil. Trans.*, 184 A, 1893, p. 361; *Phil. Mag.*, 40, pp. 437, and 447, 1895.
[2] 'Application of Hyperbolic Analysis to the Discharge of a Condenser.'

to inclose each product in brackets, and to indicate the nature of the products by the kind of bracket used, viz., round brackets for the scalar-product, square brackets for the vector-product. Thus, if small Greek letters denote vectors

$$(\alpha\beta) = \text{scalar-product},$$
$$[\alpha\beta] = \text{vector-product}.$$

Then is

$$(\alpha\beta) = (\beta\alpha); \ [\alpha\beta] = -[\beta\alpha].$$

If neither α nor β vanishes, then is

$$(\alpha\beta) = 0 \text{ the condition that } \alpha \perp \beta.$$
$$[\alpha\beta] = 0 \quad ,, \qquad ,, \qquad ,, \quad \alpha /\!/ \beta.$$

The product $(\alpha\alpha)$ is denoted by α^2.

If sums of vectors are to be multiplied, the factors are separated by a vertical line | . Thus the products of $\alpha + \beta$ into γ are written $(\alpha + \beta \mid \gamma)$, &c. Then is

$$(\alpha + \beta \mid \gamma) = (\alpha\gamma) + (\beta\gamma); \ [\alpha + \beta \mid \gamma] = [\alpha\gamma] + [\beta\gamma].$$

For these factors we have the products $(\alpha[\beta\gamma])$ and $[\alpha[\beta\gamma]]$. In the former the law of association holds, and the square brackets may be left out, so that

$$(\alpha\beta\gamma) = (\alpha[\beta\gamma]) = ([\alpha\beta]\gamma).$$

This is the volume of the parallelepiped, with α, β, γ as edges. $(\alpha\beta\gamma) = 0$ is the condition that α, β, and γ lie in a plane.

There is, besides, the formula

$$[\alpha[\beta\gamma]] = (\alpha\gamma)\beta - (\alpha\beta)\gamma.$$

These formulæ contain the whole of the algebra of vectors as far as products are concerned. Division may be altogether avoided. But it is sometimes convenient to introduce the reciprocal to a vector α, viz., by α^{-1} (not $\frac{1}{\alpha}$) is understood a vector of the same direction and sense as α, but of reciprocal length. Then is

$$\alpha^{-1} = \frac{\alpha}{\alpha^2}, \text{ and } (\alpha\alpha^{-1}) = 1.$$

The author adopts Oliver Heaviside's proposal of calling a vector whose magnitude or tensor is the *number* 1, an 'ort' (from orientation). Hence if α is an ort, then is $\alpha^2 = 1$, not the *unit of length*, but the *number* 1.

The author also adopts Maxwell's right-handed system: $\alpha\beta\gamma$, taken in cyclical order, form a *right-handed* system if standing in α and looking towards β, the third vector γ points to the *left*. The thumb, index-finger, and middle-finger, when spread out so as not to lie in a plane, form on the right hand a right-handed system, but on the left a left-handed.

A right-handed system of three vectors mutually at right angles is called a *right system.*

A right system of 'orts' he denotes generally by ι_1, ι_2, ι_3. The position vector of a point is denoted by ρ. If xyz are the rectangular coordinates (right-handed), then is

$$\rho = \iota_1 x + \iota_2 y + \iota_3 z.$$

Here xyz are *lengths*, not numbers.

Another notation found convenient is in connection with Hamilton's differential operator ∇ (called *nabla* by Maxwell). Being of the nature of a vector, it combines with a vector-function η, according to scalar- or to vector-multiplication, forming $(\nabla\eta)$ and $[\nabla\eta]$. In the former the brackets can often be left out. For the latter it is convenient to use a special symbol, viz., ∇, with an arrow-head put on top of it. As this requires a special type, formulæ involving it are given on a sheet reproduced from writing. This new symbol is called the *vector-nabla.* It is a symbol for Maxwell's *curl.*

5. *New Harmonic Analyses.* *By* Professor A. A. Michelson *and* S. W. Stratton.

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6. *The Multipartite Partitions of Numbers which possess Symmetrical Graphs in three Dimensions.* *By* Major P. A. MacMahon, *F.R.S.*

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7. *On the Quinquisection of the Cyclotomic Equation.* *By* J. C. Glashan, *Ottawa.*

If r be a primitive root of the prime number $p=5t+1$,

$$(\chi^p-1)/(\chi-1)=0$$
$$\eta_s=\chi^{r^s}+\chi^{r^{s+5}}+\chi^{r^{s+10}}+\chi^{r^{s+15}}+\ \ldots$$
$$s=0,\ 1,\ 2,\ 3,\ 4$$
$$\eta_0\eta_1=f\eta_0+g\eta_1+h\eta_2+i\eta_3+j\eta_4$$
$$\eta_0\eta_2=k\eta_0+l\eta_1+m\eta_2+n\eta_3+q\eta_4$$
$$z=5\eta+1,$$

and

$$z^5-10pz^3-5pAz^2-5pBz-pC=0,$$

then will

$$A=25(h+n)-2(p+1)$$
$$4(B+p)=A^2-125(h-n)^2$$
$$\{2C-A(B-p)\}^2=125(h-n)^2\{(B+5p)^2-4pA^2\}.$$

If

$$(\theta^5-1)/(\chi-1)=0$$
$$a=A+5(h-n)\sqrt{5}$$
$$\beta=A-5(h-n)\sqrt{5}$$
$$\gamma^2=a^2-16p$$
$$\delta^2=\beta^2-16p$$
$$64y_1^{\,5}=p(a+\gamma)^2(\beta-\delta)$$
$$64y_2^{\,5}=p(a-\gamma)(\beta-\delta)^2$$
$$64y_3^{\,5}=p(a+\gamma)(\beta+\delta)^2$$
$$64y_4^{\,5}=p(a-\gamma)^2(\beta+\delta),$$

then will

$$\eta_s=\tfrac{1}{5}(-1+y_1\theta^{-s}+y_2\theta^{-2s}+y_3\theta^{2s}+y_4\theta^{s})$$
$$s=0,\ 1,\ 2,\ 3,\ 4.$$

Two tables followed the paper, Table 1 giving the values of $f, g, h \ldots q$, Table 2 giving the values of the coefficients of the quintic in η, for all values of p from 11 to 641 inclusive.

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8. *A Kinematic Representation of Jacobi's Theory of the Last Multiplier.* *By* J. Larmor.

Consider steady flow, in a region defined by Cartesian coordinates (x_1, x_2, x_3), of fluid whose density M varies from point to point, but remains constant at the same point. If (u_1, u_2, u_3) denote the velocity, the equations of the stream lines are the integrals of the differential system

$$\frac{dx_1}{u_1}=\frac{dx_2}{u_2}=\frac{dx_3}{u_3}.$$

Suppose that one integral is known in the form

$$\phi\,(x_1, x_2, x_3)=C,$$

then the flow takes place between surfaces represented by this equation. Thus we can consider separately the flow in the two-dimensional sheet between consecutive surfaces C and $C+\delta C$; and on the understanding that the equation of continuity is satisfied, the lines of this flow will be obtained by equating a stream function ψ to a constant. For, take any two points P and Q on the sheet; the steady flow per unit time across any curve PAQ on the sheet must be equal to that across any other curve PBQ, provided there is no sink in the region between these curves into which fluid can disappear. Thus the flow across any curve connecting P and Q must be a function of the coordinates of these points, say F (P, Q); further, since the flow across PQ is the sum of those across PB and BQ, this function must be of the form $\psi(Q)-\psi(P)$. If therefore τ denote at each point the thickness of the sheet, and v the component velocity at right angles to the element of arc ds on it,

$$\int_P^Q Mv\tau ds = \psi(Q)-\psi(P);$$

that is $Mv\tau ds$, which is of the form $G_1dx_1+G_2dx_2+G_3dx_3$ is the exact differential of a function $\psi(x_1, x_2, x_3)$. Thus if one integral of a linear differential system

$$\frac{dx_1}{u_1}=\frac{dx_2}{u_2}=\frac{dx_3}{u_3}$$

is known the remaining one can be found by a quadrature whenever a value of M is known which satisfies the equation of continuity

$$\frac{d(Mu_1)}{dx_1}+\frac{d(Mu_2)}{dx_2}+\frac{d(Mu_3)}{dx_3}=0.$$

This argument admits of immediate extension to hyper-space involving any number n of Cartesian coordinates. In that case a knowledge of $n-2$ integrals determines an equal number of systems of hyper-surfaces along which the flow takes place; these divide the region into two-dimensional sheets, the flow in each of which takes place independently and is determined by a stream function, as above, whose general form can be determined by a quadrature.

This is Jacobi's proposition. The conditions of its application are satisfied by the special value $M=1$ in the case of the differential equations of isoperimetrical problems, including the general equations of dynamics.

In all cases of course values of M exist, but it is only sometimes that they can be analytically expressed. One method of trial is to express the determining equation, after Jacobi, in the form

$$\frac{\delta M}{dx_1}=-\frac{1}{u_1}\left(\frac{du_1}{dx_1}+\frac{du_2}{dx_2}+\ \ldots\ +\frac{du_n}{dx_n}\right),$$

in which δ represents a total differentiation. If then by means of the $n-2$ known integrals the quantity on the right-hand side can be expressed as a function of x_1 alone which is capable of integration, its integral is a form of M.

In three dimensions the flow across a differential arc PQ, say ds on the sheet, is equal to a lamellar element of volume whose projection on the plane x_1x_2 is $\begin{vmatrix} dx_1 & dx_2 \\ u_1 & u_2 \end{vmatrix}$ and whose height parallel to the axes of x_3 is dx_3, where $dC=\frac{d\phi}{dx_3}dx_3$; thus it is $M\div\frac{d\phi}{dx_3}.(u_2dx_1-u_1dx_2)\delta C$, which is accordingly an exact differential in dx_1 and dx_2. In n dimensions it is similarly

$$Mdx_3dx_4\ \ldots\ dx_n\begin{vmatrix} dx_1 & dx_2 \\ u_1 & u_2 \end{vmatrix},$$

that is $M(u_2dx_1-u_1dx_2)\delta C_1\delta C_2\ldots\delta C_{n-2}\div\frac{d(\phi_1\phi_2\ldots\phi_{n-2})}{d(x_3x_4\ldots x_n)}$,

which is thus an exact differential when expressed in terms of x_1 and x_2.

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9. *Increase of Segmental Vibrations in Aluminium Violins.* *By* Dr. A. Springer.

Continued experiments made with aluminium sound boards have verified the statements made by the author five years ago, that aluminium possesses acoustical properties more closely allied to those of wood than those of metals. Metals in general give rise to comparatively continuous and uniform maintenance of higher upper partial tones, frequently inharmonic to the prime, making the tone extremely penetrating and unmusical. In wood the mass is small, the natural structure irregular, being full of countless interstices, the elasticity comparatively imperfect causing the higher proper tones to rapidly die away. Aluminium not only possesses the latter property, but to a much more marked degree; on account of its lightness and probably intermolecular friction the higher upper partials require special construction of a sound board to become audible. In wooden instruments provision must be made to prevent the bass notes from entering into segmental vibrations detrimental to upper partials, thereby giving a dull purity of tone, lacking in brilliancy. To avoid this effect the author was obliged to depart from the fixed rules adopted by violin makers and work in a manner diametrically opposed to them.

The author showed by means of open model an aluminium cross section under the bridge instead of bass bar and a reinforcement of centre of the belly and back, by which means the segmental vibrations are produced.

After the paper was read a violinist played on one of the instruments exhibited, illustrating the various points discussed.

Department II.—Meteorology.

1. *Report on Observations at the Ben Nevis Observatory.* See Reports, p. 219.

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2. *Report on the Application of Photography to the Elucidation of Meteorological Phenomena.*—See Reports, p. 128.

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3. *Monthly and Annual Rainfall in the British Empire,* 1877 *to* 1896. *By* John Hopkinson, *F.R.Met.Soc., Assoc.Inst.C.E.*

Nearly twenty-four years ago there appeared in 'The Colonies' a letter from Mr. W. Sowerby suggesting that residents in the British Colonies should be invited to contribute notes and queries on natural objects. This was followed by a letter from Mr. G. J. Symons, F.R.S., adding a similar plea on behalf of Meteorology. These suggestions met with the approval of the Editor of 'The Colonies,' and he invited the Directors of the principal Colonial Observatories to supply monthly reports of meteorological observations, and arranged with Mr. Symons to supervise them.

The first table published was for January 1874, and contained reports from sixteen meteorological stations in the British Empire. The tables were continued to June 1881, after which date they have appeared in Symons' 'Monthly Meteorological Magazine.' In the table for December 1896 are records from eighteen stations, but only seven of these are survivals from January 1874. The rainfall at ten of these stations can be carried back for at least twenty years, and

that at two for at least ten years. The ten stations with a twenty years' record are London, England (Camden Square); Port Louis, Mauritius; Calcutta and Bombay, India; Colombo, Ceylon; Adelaide and Melbourne, Australia; Wellington, New Zealand; and Toronto and Winnipeg, Canada; the two with a ten years record are Malta and Kingston, Jamaica.

In a series of tables are given the mean monthly and annual rainfall and number of days on which at least 0·01 inch of rain fell at these twelve stations, and also the maximum and minimum monthly and annual rainfall and number of days of rain. A summary of these twelve tables is then given. The means in this table are those of the ten stations with records for twenty years, but the extremes are those for the whole of the twelve stations. This table is followed by a summary of the yearly rainfall at the twelve stations.

It must not be inferred that the rainfall at the places selected represents the mean rainfall of the countries in which they are situated. These places are in most cases the principal towns in those countries. Nor are the extremes of the rainfall in the British Empire represented. But it is believed that no previous attempt has been made to ascertain the mean rainfall at nearly so many as ten widely distributed places in the British Empire for nearly so long a period as twenty consecutive and concurrent years. The observations, moreover, have been taken in an entirely uniform manner, and are believed to be thoroughly trustworthy, the results being strictly comparable one with another.

A few observations are then made on the rainfall at the various places, and finally a summary of the principal results is given.

Throughout the British Empire, so far as appears from these observations, the mean rainfall is least in February and greatest in July, increasing every month from February to July, and decreasing every month from July to February. There may be no rain at some one or more of these rainfall stations in any month in the year up to six months in succession. The heaviest fall in any month was 47·64 inches at Bombay, in July 1878, and only here has there been rain on every day in any month. In Malta, in 1895, the rainfall was only 11·38 inches; at Colombo, in 1878, it was 139·70 inches. In Malta, in 1888, there were only 59 days of rain; in Mauritius, in 1893, there were 241 wet days.

If the twenty years be divided into four periods of five years each it will be found that the mean annual rainfall at the ten stations has been as follows:—In the first period 47·15 inches on 150 days; in the second period 44·67 inches on 147 days; in the third period 44·21 inches on 155 days; in the fourth period 44·15 inches on 151 days. This does not show much deviation except in the first period (1877-81). This was an exceptionally wet period in England, and now appears to have been generally wet. The mean annual rainfall for the first ten years was 45·92 inches on 149 days, and for the last ten years 44·67 inches on 153 days. For the whole period it was 45·29 inches on 151 days.

In this account of the rainfall at a few meteorological stations in the British Empire, the effects of the seasons have been altogether neglected. Six of the stations with records for twenty years are north of the equator and four are south of it, not a very great inequality. In England the wettest period is nearly the same as in New Zealand, but it happens to be in the summer and autumn in England when in New Zealand it is winter and spring. And taking each place individually there seems to be very little correspondence between the rainfall and the season. It does not appear to be the succession of the seasons which causes the rainfall to increase generally each month from February to July and to decrease each month from July to February, although the very heavy rainfall at Bombay in June and July tells much in making those months appear to be so wet on the average throughout the Empire.

With a larger number of stations any such disturbing influence as this would be neutralised, and it may be worthy of consideration whether it might not be well to appoint a small Committee of the British Association to collect and digest statistics of the rainfall from a large number of places in the British Empire.

Mean Rainfall and Number of Days on which at least 0·01 *inch of Rain fell at Ten Stations in the British Empire, and Extremes at Twelve Stations.*

—	Mean		Maximum		Minimum	
	Inches	Days	Inches	Days	Inches	Days
January	2·28	9	14·58	25	·00	0
February	2·08	9	30·06	27	·00	0
March	2·64	10	24·11	26	·00	0
April	3·29	11	28·78	27	·00	0
May	3·89	13	22·28	28	·00	0
June	6·04	16	43·45	28	·00	0
July	6·48	17	47·64	31	·00	0
August	5·06	17	36·56	31	·00	0
September	4·23	15	25·08	26	·00	0
October	3·84	13	35·28	30	·00	0
November	3·00	11	28·78	27	·00	0
December	2·46	10	17·72	24	·00	0
Year	45·29	151	139·70	241	11·38	59

Mean and Extreme Yearly Rainfall, and Number of Days of Rain at Ten Stations in the British Empire for Twenty Years, and at Two for Ten Years.

—	Mean		Maximum		Minimum	
	Inches	Days	Inches	Days	Inches	Days
1877–96.						
London	25·76	164	34·09	195	19·21	137
Mauritius	50·38	203	68·17	241	29·74	174
Calcutta	59·20	116	85·23	143	39·38	74
Bombay	76·71	111	111·93	124	57·82	102
Colombo	91·82	179	139·70	215	60·55	126
Adelaide	20·56	135	30·87	164	14·01	113
Melbourne	24·52	132	32·39	153	17·06	116
Wellington	51·22	170	67·68	191	31·37	137
Toronto	31·49	177	48·51	206	24·83	143
Winnipeg	21·22	127	29·33	159	14·64	88
1887–96.						
Malta	20·50	79	26·04	90	11·38	59
Jamaica	29·16	85	40·81	97	19·01	78

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4. *On the Temperature of Europe. By* Dr. van Rijckevorsel.

The material to which the following remarks refer consists of a large number of temperature curves deduced from observations at places scattered over the whole of Europe. They were obtained by smoothing down in the very simplest fashion the mean temperature for each day of the year. On throwing even a passing glance at those curves one is forcibly struck at once by two facts.

The first is that the climate of Europe is divided between two different types, the one being the eastern type, prevailing in Russia and some parts of adjacent countries, the other the western one, covering the rest of our continent.

The second fact is that in each of these two large divisions all the curves are strikingly similar.

I think that the most interesting thing in those curves is, not their general appearance, but the irregularities, the secondary maxima and minima. These may

indicate a way to detect and explain a great many peculiarities of our climate. Many of these have hitherto either not been paid attention to, or have been considered as slight anomalies; yet they seem to be most permanent and important features.

A few of these anomalies—for instance, one consisting of two unimportant maxima, separated by a more or less apparent minimum in April—spread over the whole of Europe. Is it altogether impossible that one or more of such features are not confined within the limits of Europe? Should any of them be found to prevail over a whole hemisphere, or farther still, ought we not to look beyond the earth for their origin?

Other anomalies, however, have a smaller range. Two remarkable instances of this are two very pronounced mimima which characterise the summer in western Europe. The more important one at the end of July, separating two nearly equal maxima in the middle of June and the middle of August, is strongly prominent on the coasts of the Atlantic and the North Sea, and slowly decreases in the centre of Europe, dying out at the Russian frontier. The other one, a similar minimum, about a month earlier, is also strongest on the north-western shores of our continent, but dies out much sooner: it can hardly be detected beyond the eastern frontier of France. Here we have, I venture to affirm, two effects of causes which, whatever they may be, must lie to the west of us, in the Atlantic or beyond.

Another feature, on the contrary, a minimum in the second half of December, with a very decided rise of temperature towards the end of the year, which is very characteristic for the extreme east of our continent, dies out long before it could reach the middle of Russia. We owe this effect apparently to something in Asia, or beyond.

I forego to discuss in this short abstract some other advantages arising from a systematic discussion of temperature curves. Such are a possible indication of something being wrong in the exposures of thermometers; the possibility of getting very good results with what would hitherto have been considered absolutely insufficient material; the possibility of giving a near approximation to normal temperatures for any station *à priori*, &c.

But what I think is principally shown is—

(1) That it is not so much the general knowledge of the temperature of a place that is interesting as the irregularities, even such small ones as one is tempted at first to ascribe to errors of observation or such like causes;

(2) That here is an excellent way to find out, not indeed what the ultimate causes of such irregularities are, but in which direction to look for them. One glance at the diagrams generally instantly shows that some interesting anomaly, such as I gave a few instances of, originates to the west, the east, or the south of our continent.

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5. *The Climatology of Canada.* *By* R. F. Stupart.

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6. *The Great Lakes as a Sensitive Barometer.* *By* F. Napier Denison, *Toronto Observatory.*

For many years fishermen and sailors upon the great lakes have noticed with intense interest the rapid rise and fall of the water, most marked at the head of shallow lagoons or bays. The phenomenon is not uncommon, having been ably studied upon the Swiss lakes by Professor Forel and his predecessors, Duillier, De Saussure, and others, where it obtained the name of 'Seiche,' and also by Mr. Russell, F.R.S., upon Lake George, New South Wales. The writer's attention was first drawn to this subject last summer, while in the vicinity of Lake Huron, where a set of observations were taken. Upon returning to Toronto, by permission of Mr. Stupart, Director of the Meteorological Service, a simple instrument was devised for automatically recording these oscillations, and was set up at the mouth of the Humber River, near Toronto. Shortly afterwards a similar

instrument was placed at the west end of the lake at the Burlington Canal. The records from these two instruments, when studied in conjunction with the Observatory synoptic weather charts and barograph traces, have revealed many interesting points. Last January, to obtain a better knowledge of the smaller barometric movements, a simple form of self-recording air barometer was constructed, seventeen times more sensitive than the mercurial. This again has recently been superseded by a combined self-recording water-level instrument and air barometer—that is, both pens record upon the same time-sheet where an hour equals one inch and one complete revolution of the cylinder equals twenty-four hours.

The following are some of the results deduced from the records:—

1. That the longitudinal and transverse 'Seiche' movements are very marked preceding and during storms primarily due to differences of atmospheric pressure over the extremities of the lake, but greatly augmented when the gale strikes the water surface. The mean time interval of longitudinal 'Seiche' is four hours and forty-nine minutes; the transverse, forty-five minutes.

2. There is a marked agreement between the time intervals of the smaller lake undulations and those found upon the corresponding sensitive barograph traces, both showing a predominance of twenty-minute intervals.

3. These smaller lake undulations are due to atmospheric waves which are set up along the boundary surfaces of different air strata when travelling in opposite directions, the existence of which have been so clearly demonstrated by the late Professor von Helmholtz in his mathematical papers read before the Royal Prussian Academy of Sciences at Berlin in 1889 and 1890.

4. The action of these atmospheric waves upon the surface of the water tends to form minute undulations, which increase in amplitude as they move into bays, &c., where the water becomes shallower, until finally they assume the proportions as recorded upon the instrument.

5. It appears, from a careful study of the Canadian ocean tidal records, placed at the writer's disposal through the kindness of Mr. W. Bell Dawson, Director of the Tidal Survey, in conjunction with the synoptic weather charts, that the secondary undulations found upon them may also be due to similar atmospheric action.

6. Marked rapid and large undulations often occur during the autumn and winter months upon both instruments when the barometer is actually rising and fine weather prevails throughout Ontario. At such times an area of low pressure, or cyclone, is situated over the south or south-western States, which usually moves over or near to the lake region. In such cases the recorded atmospheric waves are due to the lower, denser air of the anticyclone, moving towards the south-western cyclone, along whose upper boundary surface huge waves, extending to the earth, are set up by the rapidly opposing upper poleward current. The mean velocity of this upper current in summer is sixty miles per hour, and in winter one hundred and ten miles per hour. On the other hand, during the approach of an anticyclone, attended by fine weather and westerly winds, these lake undulations become extremely small, because the lower air moves in approximately the same direction as the upper poleward current.

7. The direct action of these air waves upon the surface of the lake is clearly shown during the passage of a thunder shower. As an instance, on March 8 last, during the passage of several successive huge atmospheric 'billows,' the water rose $8\frac{1}{2}$ inches in ten minutes, then fell $10\frac{1}{2}$ inches in fifteen minutes, followed by the phenomenal rise of $11\frac{1}{2}$ inches in fifteen minutes.

8. These records graphically explain the cause of those erroneously termed 'tidal waves' which occur upon the lakes, and also tend to solve the problem respecting the larger waves encountered at apparently regular intervals. From information obtained from fishermen on Lakes Erie, Ontario, and Huron a twenty-minute interval appears to have been frequently observed between these waves.

As these peculiar undulations occur upon all waters it is hoped the study of them will become more universal, and the time not far distant when instruments similar to those described will be adopted throughout the scientific world.

7. *Slow Refrigeration of the Chinese Climate.* *By* Dr. J. Edkins.

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8. *Progress of the Exploration of the Air with Kites at Blue Hill Observatory, Mass., U.S.A.* *By* A. Lawrence Rotch, *S.B., A.M., F.R.Met.Soc., Director.*

A preliminary report on the subject was presented to this Section at the Liverpool meeting of the British Association, and, in consequence of the successful results which had been obtained at Blue Hill, this method of exploring the free air was endorsed by the International Meteorological Conference which met in Paris last September.

Many improvements in the kites and apparatus have been effected during the past year, and, through the aid afforded by a grant from the Hodgkins Fund of the Smithsonian Institution, the first steam-reeling apparatus for kites has been constructed. Since August 1894, when an instrument recording continuously and graphically its indication was for the first time lifted by kites, 130 records of barometric pressure, air temperature, and relative humidity, or of wind velocity, have been obtained up to the extreme altitude of 8,740 feet above Blue Hill. This height, which was attained last October, is believed to be the greatest to which a meteorograph has been raised by kites (see 'Nature,' December 17, 1896). Nine records have been obtained more than a mile above the hill at all seasons of the year, both in fine and in stormy weather.

The data have been discussed and are about to be published in the 'Annals of the Harvard College Observatory.' They furnish some important facts concerning the changes of temperature, relative humidity and wind in the free air, under varying atmospheric conditions, and constitute the most thorough exploration of the lower mile of free air ever made in any manner. Since warm and cold waves appear to commence in the upper air it seems probable that daily observations with kites would aid in weather forecasting, and the experiment is to be tried by the United States Weather Bureau at several stations. Meanwhile the investigation is being continued at the Blue Hill Observatory, with the hope of obtaining data two or three miles above the earth, and kites are serving to supplement the measurements of the heights of clouds made by the methods prescribed by the International Cloud Committee.

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9. *Kites for Meteorological Uses.* *By* C. F. Marvin.

The author gave an account of the initiation of the investigation by the Weather Bureau at Washington of the availability of kites for making daily observations in the free air.

He then described and showed a full-sized model of the improved kites as now employed by the Weather Bureau, and referred to methods of bridling the kite to secure approximately constant pull upon the string under wide variations in the wind force; also to the use of a 'safety line' upon the kite, corresponding in function to the well-known fusible plug in electrical circuits.

A brief outline of the mechanics of the kite was given, and remarks were made upon the flying of kites in tandem.

In conclusion the results thus far attained were discussed.

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10. *Meteorites, Solid and Gelatinous.* *By* Dr. Otto Hahn.

The author gave an account of bodies found in the meteorite of Kinyahinga, which fell on June 6, 1866. These he considers to be organic, sponges, &c.

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11. *November Meteors and November Flood Traditions.* *By* R. G. Haliburton.

TUESDAY, AUGUST 24.

The Section was divided into two Departments.

The following Papers and Report were read:—

DEPARTMENT I.—ELECTRICITY.

1. *Demonstrations on the Form of Alternating Currents.* *By* Professor Dr. F. BRAUN, *Strassburg.*

Ein Kathodenstrahl wird in einem Magnetfeld, welches durch einen Wechselstrom erzeugt ist, abgelenkt. Der vom Kathodenstrahl auf einer fluorescirenden Fläche erzeugte Fleck macht daher Schwingungen, welche in einem rotirenden Spiegel analysirt werden können. Wirken auf den Kathodenstrahl zwei unter einem rechten Winkel gekreuzte Felder, so entstehen Lissajous'sche Curven, welche gestatten Phasenverschiebungen der Felder in Folge von Selbstinduction, Capacität, Polarisation, u.s.w., nachzuweisen und zu messen. Eine Trägheit des Kathodenstrahles konnte nicht gefunden werden; den Schwingungen von Leydener Flaschenentladungen folgt er noch. Eine magnetische Wirkung von Lichtstrahlen wurde aber vergebens gesucht. Ein dem Kathodenstrahl mit seiner Axe parallel gestellter Magnet breitet denselben zu einem Gebilde aus, wie es entstehen müsste, wenn der Kathodenstrahl ein beweglicher Stromleiter wäre; ob aber dieses Gebilde entsteht durch eine ausserordentlich rasche Rotation oder ob es ruht, ist unentschieden. Von Interesse ist es, dass das Magnetfeld der Erde schon hinreichend stark das Ende des Kathodenstrahles ablenkt, so dass jedenfalls angenäherte Bestimmungen der Inclination damit möglich sind.

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2. *Note on an Electrical Oscillator.* *By* NICOLA TESLA.

The instrument exhibited belongs to a novel class of electrical transformers, the primary of which is operated by the oscillatory discharge of a condenser. The above name seems, therefore, particularly appropriate.

The condenser is charged from any suitable, direct or alternating, current source.

By observing the well-known conditions governing the oscillatory discharge of the condenser, which have been established by Lord Kelvin, and selecting properly the physical constants of the primary or "discharge circuit," extremely rapid oscillations in this circuit are obtained, which set up, by inductive action, corresponding high-frequency current impulses in the secondary circuit.

The fundamental disturbances in the primary circuit are produced either by simply adjusting the quantities concerned, so that the average rate of supply of energy to the condenser shall be inferior to the average rate of discharge, or else positively-acting mechanical means, irrespective of such adjustment, are employed to periodically open and close the circuit.

The circuit connections in the instrument exhibited are indicated in a diagram, while a photograph showed the actual arrangement of the parts in the instrument.

Referring to these illustrations, the condenser is contained in a box, upon which is mounted in front the circuit controller, consisting of spring contacts, and a self-induction coil. The latter, designated as a "charging coil," serves at the same time to raise the pressure of the source to any value desired for charging the condenser. This is an important practical advantage, as it enables the capacity of the latter to be reduced, so that it need not be more than a few per cent. of that otherwise required for an equivalent conversion of energy. Besides, the smaller the capacity, the quicker is the oscillation, and the shorter need be the high-tension secondary wire.

The primary or discharge circuit surrounding the secondary coil or coils is formed of a few turns of copper ribbon mounted on the top of the box behind the

"charging coil," all connections being as short as possible, so as to reduce, as much as it is practicable, both the resistance and self-induction of this circuit.

On the front side of the box containing the condenser there are mounted two binding posts for connection with the lines, two small fuses, and a reversing switch. In addition two adjusting screws are provided for raising and lowering the iron core within the charging coil as a convenient means for varying within considerable limits the current of supply, and regulating thereby the discharge of the secondary circuit. In adjusting the core the left-hand screw should be unscrewed first, as it performs merely the function of a check-nut.

The mode of operation may be explained in current language as follows:—

At the start the spring contacts being closed and the condenser practically short-circuited, a strong current passes through the "charging coil," attracting the armature fastened to the lower spring, and separating the contacts. Upon this the energy stored in this coil, assuming the form of a high-tension discharge, rushes into the condenser, charging the same to a high potential. The current through the coil now subsiding, the attraction exerted upon the armature ceases, the spring reasserts itself and again closes the contacts. With the closing of the latter the condenser is discharged through the primary, and simultaneously a strong current from the source of supply again rushes through the charging coil, and energy is stored for the next charge of the condenser, this process being repeated as often as the spring opens and closes the contacts.

By means of this simple arrangement certain advantages over ordinary coils are secured, the chief being the absence of fine wire in the secondary, the quality of the effects produced, and efficiency.

The photograph, showing the instrument in action with two loops of cotton-covered wire attached to the discharge rods, conveys an idea of the pressures obtained. The outer wire loop was in the experiment only 22 inches in diameter, to enable its being properly shown in the print, but it could have been much larger, since two parallel wires, 15 feet long, may be stretched from the secondary terminals of the instrument, and practically the entire space between them, $3\frac{1}{2}$ inches wide, is seen in the dark covered with fine streamers—that is, a surface of over 4 square feet—and yet the energy taken from the supply circuit during the performance is less than 35 watts. It is practicable, by the use of the principle described, to obtain sparks of 1 foot in length with an expenditure of energy of less than 10 watts.

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3. *An Electric Curve Tracer.* *By* Professor E. B. Rosa.

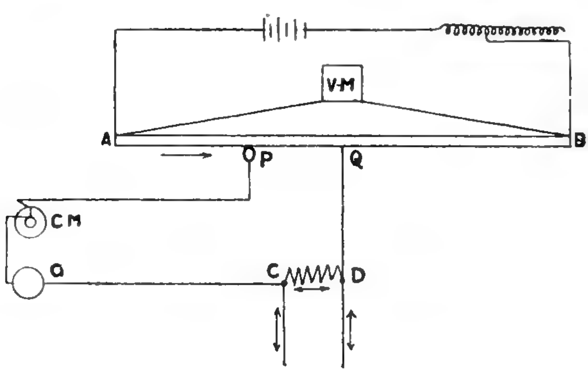
One of the most interesting and fruitful methods of investigation of alternate current phenomena is the tracing of the forms and phases of current and electromotive force waves. But the practicability of this method of investigation and testing has been seriously limited by the great labour of obtaining the curves, and the insufficient accuracy of the curves when obtained. Although various methods are employed for determining the quantities from which to plot the waves of current and electromotive force, yet in nearly every case an instantaneous contact-maker is used, and the contact brush is advanced by hand, step by step, settings being made on a graduated circle. Readings are taken on a voltmeter, electrometer, or galvanometer, and subsequently points are plotted out on cross-section paper, and a smooth curve drawn through them. Because of the great labour involved, comparatively few points are usually found, and hence the curves are only approximately determined. To reduce the labour and increase the speed of working would enable a greater number of points to be determined, and so give more faithful representations of current curves. This could be accomplished by some arrangement that would do the most laborious part of the work mechanically, and, if possible, automatically. Hence, if successive settings of the brush of the contact-maker could be made quickly and easily, and the curve printed out automatically, so as to eliminate the necessity of taking readings and plotting the points, the thing would be done. It was to accomplish this end that I had an

instrument constructed last year in our college machine shop. The instrument worked well and gave some very elegant results. But there appeared in its use several practical defects which experience showed how to remedy, and this year I have constructed a new instrument, which may be called an Electric Curve Tracer, and which will now be briefly described.

The instrument consists of three parts: (1) the Contact-Maker, (2) the Measuring Selenoid, and (3) the Recording Cylinder. The *Contact-Maker* is joined by a rod and flexible couplings to the shaft of the dynamo, which produces the current to be delineated, or to a synchronous motor which is driven by that current. Hence the shaft of the contact-maker, and with it a hard rubber disc six inches in diameter, revolves with the speed of the armature of the alternator. The brush which, once in every revolution, makes contact with a knife-edge let into the edge of the hard rubber disc, is carried by an arm which is advanced step by step by a ratchet wheel and gearing. The pawl of the ratchet is actuated by an electro-magnet, and the step of the brush is half of one degree for each tooth of the ratchet wheel. Any number of teeth from one to six may be taken at each step, according to the position of the stop. The current through the electro-magnet, which advances the brush, is made by the operator at the measuring and recording apparatus, which may be at a distance.

The *Measuring Solenoid* consists of a single layer of insulated wire wound

FIG. 1.

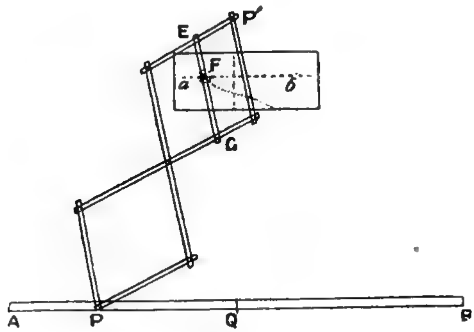


upon a hard rubber rod 80 centimeters in length; along one element of this solenoid the insulation is removed. A current from two or three storage cells passes through the solenoid from A to B, and by means of a voltmeter and rheostat the difference of potential between A and B is kept constant. This spiral has so much greater length of wire than a single wire, such as that on a slide wire bridge, that it can maintain a much greater difference of potential, and serves the purpose better than a single wire would do. Let the current to be delineated pass through the non-inductive resistance C D. We measure the instantaneous difference of potential at the terminals of C D by matching it against the known difference of potential of a portion of A B. This is done by joining Q, the middle point of A B to D, and P, a sliding contact on A B, to C, through the instantaneous contact-maker and a sensitive, dead-beat D'Arsonval galvanometer. When P is so adjusted that there is no deflection of the galvanometer, the potential difference between C and D is the same as that between P and Q, and the latter is proportional to the distance P Q. If the current at the instants of contact is from C to D, then the potential of C is higher than D, and P will be on the left of Q; if the current is from D to C, P is on the right of Q. In either case the strength of the current is proportional to the difference of potential between C and D, and therefore to the distance P Q. At each step of the brush contact is made at a later instant in the period of the wave; the current has a different value, and hence P must be moved to keep the galvanometer deflection zero. The spiral being of constant diameter, and uniformly wound, these distances P Q give

accurate values of the current. Using these distances as ordinates, and the corresponding angular positions of the brush on the revolving contact-maker as abscissas, a curve of current can be plotted, its scale being, of course, determined by the value of the constant resistance C D through which the current passes, and the value of the constant potential difference between the ends of the solenoid.

But to eliminate the labour of taking scale readings and plotting the curves it

FIG. 2.



is arranged to plot them out automatically as the successive settings of P along the solenoid are made. A pantagraph has one end fixed at P′, and the other attached to the sliding contact P. The bar E G of the pantagraph carries a printing point F. As P is moved to and fro upon the solenoid, F travels to and fro along *a b*, parallel to A B. And since P′*f* is one-fifth of P′P, the excursions of F are one-fifth of those of P. When each setting of P has been made, the printing point F is depressed by an electromagnet, and a dot is made upon a sheet of cross-section paper underneath. Between the successive settings the paper is advanced a step perpendicularly to *a b*. In this way a current curve is plotted to a known scale, and by repeating the process with other currents through C D (as, for example, the secondary current, due to the induction of the first one, or an electromotive force current) several waves may be delineated on the same sheet, each to a known scale, and their relative phases shown by their relative positions.

In order to advance the paper conveniently by equal steps it is wrapped upon a cylinder, which is advanced step by step by a ratchet wheel and gearing, actuated by an electromagnet, precisely as the contact-maker is operated. These two electromagnets, and that on the pantagraph, are controlled by the same key, and all work together. Closing the key causes the steel point F to be thrown down upon a type-writer ribbon, which prints a point on the paper beneath; it also causes the armatures of the two driving magnets to be attracted, and the pawls to slip back over one or more teeth of the ratchet, until the armatures strike their respective stops. Breaking the circuit allows the printing point to be lifted by a spring, and the armature of the driving magnets to be drawn back to their initial positions by their springs. The two pawls at this time advance their respective ratchets; one advancing the brush of the contact-maker, and the other the cylinder carrying the record sheet, ready for a second point. The sliding contact P is moved by means of a cord passing over pulleys at the ends of A B, and wound over a small drum underneath the solenoid, the drum being turned by means of a large milled head. The operator turns this drum with one hand, and closes the key with the other, keeping his eye constantly on the galvanometer scale. With a quick, dead-beat galvanometer the settings are made very rapidly, and it is no unusual performance to print off a curve at the rate of twenty or more points per minute.

If the curve closely approximates to a sine curve, and there are no high harmonics present, the points may be further apart, and the ratchet of the recording cylinder advanced four or six teeth at a time. If there are upper harmonics,

and one wishes a faithful representation of the curve, two teeth are taken at a time, and 180 points plotted in one single wave-length, which extends half-wave around the recording cylinder.

If the generator is a two-pole machine, four teeth will be taken at one step on the contact-maker and two on the recording cylinder. If it is a four-pole machine, an equal number of teeth will be taken on each. If it is an eight-pole machine, one tooth is taken on the contact-maker and two on the recording cylinder, and so on. In each case the resulting curves will be drawn to the same horizontal scale.

Special attachments are provided for printing copies of original curves, for making curves of magnetisation and hysterisis curves, and also for taking power curves—in the latter case not by multiplying corresponding ordinates of current and electromotive force curves, but plotting directly from the settings of the contact piece P.

The accuracy of the work of the instrument is illustrated by curves, representing the current flowing into a condenser from the secondary of a transformer (which were exhibited). The capacity of the condenser for the second curve is double that of the first, other circumstances being the same. The curves show a little more than a wave length and a half of the fundamental, but the character of the curves is determined by their upper harmonics, the natural period of the condenser-transformer circuit being such as to amplify very small upper harmonics in the electromotive force of the dynamo, which had a toothed armature. In the second curve the period is larger (because the capacity is greater), and the free vibrations, which are superposed on the fundamental, are accordingly fewer in number. Comparing one half-wave with another, it is evident that the curve-tracer has done its work faithfully. Without a large number of points in the space of one wave we should fail to apprehend the true character of such curves. The instrument lends itself to a great variety of purposes. One can study the actions and reactions in dynamos and motors, of single and polyphase varieties; in transformers of all types, and of special devices in practical or abstract research. By means of a two-part commutator on the shaft of the contact-maker the oscillating currents of condenser charges and discharges can be delineated, and the period measured. Curves showing the rise and fall of current in inductive circuits when the current is made and broken can be drawn, and the self-induction thereby measured.

I wish to express my obligations to Mr. O. S. Blakeslee, the accomplished mechanician of the college, for his assistance in designing the mechanical features of the Curve Tracer, and for his skill in constructing the instrument.

The *equations* of the two curves are as follows:—

1st. $I = 8{\cdot}79 \sin(x - 18°50') - 1{\cdot}02 \sin(3x - 44°18') + 2{\cdot}55 \sin(5x + 84°31') - {\cdot}41 \sin 7x - 2{\cdot}95 \sin(9x - 5°43') + 1{\cdot}88 \sin(11x + 34°36') + 8{\cdot}08 \sin(13x + 10°7') + 5{\cdot}45 \sin(15x - 59°56')$.

2nd. $I = 18{\cdot}75 \sin(x - 21°6') - 2{\cdot}18 \sin(3x - 70°1') - 6{\cdot}86 \sin(5x + 61°48') - 1{\cdot}56 \sin(7x - 84°7') + 5{\cdot}30 \sin(9x + 66°14') + 0{\cdot}98 \sin(11x - 83°30') + 4{\cdot}15 \sin(13x - 43°30') + 3{\cdot}59 \sin(15x - 86°30')$.

The 17th and higher harmonics not present to an appreciable extent.

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4. *On the Use of the Interferometer in the Study of Electric Waves.* *By* G. F. Hull, *University of Chicago.*

An interferometer for electric waves, constructed after Michelson's form, was used to analyse electric radiation. A Branly receiver (small nails in oil) and different forms of Righi's vibrators were used. The following conclusions were arrived at:—

1. The interference curve depends on both vibrator and receiver, and the influence of each of these varies.

2. The logarithmic decrement of the receiver is of the same order of magnitude as that of the vibrator.

3. The chief component of the radiation and the period of the receiver may be determined by a number of interference curves.

4. The receiver could be used to analyse the radiation, where the oscillations are but slightly damped.

5. The error in determining the wave-length and the index of refraction need not exceed 1 per cent.

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5. *An Instrument for Recording Rapidly Varying Potential Differences and Currents.*[1] *By* W. DUDDELL.

The methods and instruments generally employed for this purpose may be divided into two classes, viz. 'contact or point methods' and 'continuous methods.'

This latter class may be subdivided according to the nature of the moving part acted on by the varying current.

The present instrument belongs to that division in which the moving part consists of wires carrying the current to be measured, and in its present form was first suggested by Blondel.

The instrument consists essentially of a pair of phosphor bronze strips stretched tight in a strong magnetic field, to the middle points of which a small mirror is fixed.

The current flows up one strip and down the other, causing one to move forward and the other to move back, and thus turning the mirror through a small angle. The source of light used is an arc lamp and a system of lenses, the motion of the spot being recorded on a falling photographic plate, or observed in a rotating mirror.

The necessary damping is obtained by immersing the strips in oil and adjusting the temperature until it is correct.

In the instrument shown two pairs of strips and a fixed mirror were used, so that both the current and P.D. curves, as well as the zero line, were traced on the plate at the same time, thus giving, as well as the two curves, their phase difference and the periodicity from the known velocity of the plate.

The free periodic time of the strips and mirror is about $\frac{1}{3000}$ sec., and a current of $\frac{1}{10}$ cm. amp. gives a deflection of 1·53 cm. at a screen distance of 136 cms.

The chief advantages of the instrument are the low self-induction and resistance, as well as the critical damping.

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6. *Report on Electrical Standards.* See Reports, p. 207.

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7. *On the Calculation of the Coefficient of Mutual Induction of a Circle and a Co-axial Helix.* *By* Professor J. VIRIAMU JONES, *F.R.S.*

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8. *On a Determination of the Ohm made in Testing the Lorenz Apparatus of the McGill University.* *By* Professor W. E. AYRTON, *F.R.S., and* Professor J. VIRIAMU JONES, *F.R.S.* *Appendix to Electrical Standards Report.*—See Reports, p. 212.

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9. *On the Relations between Arc Curves and Crater Ratios with Cored Positive Carbons.* *By* HERTHA AYRTON.

When an arc is burning between a solid negative carbon and a positive of given diameter, the P.D. between the carbons varies according as the positive carbon is cored or solid.

[1] Published in the *Electrician*, Sept. 10, 1897.

When the Length of the Arc is kept Constant and the Current is varied.

1. The P.D. is in all cases higher with the solid than with the cored carbon.

2. With a solid carbon the P.D. continually diminishes as the current increases; with a cored carbon the P.D. either diminishes much less than with a solid carbon, or remains constant for all currents above a given value, or actually increases with the current after falling to a minimum.

Current is kept Constant and the Length of the Arc is Varied.

1. The P.D. is always higher with solid carbons than with a cored positive carbon, but the difference between the two diminishes as the arc increases in length.

2. The rate of change of P.D. with change of length is constant with solid carbons, but diminishes as the length of the arc increases with a cored positive carbon.

3. This rate of change becomes smaller and more nearly constant for all lengths of arc as the value of the constant current increases.

4. The P.D. corresponding with length of arc 0 diminishes as the current increases with solid carbons, but increases with the current with a cored positive carbon.

These differences can all be accounted for on the hypothesis that *with a given solid negative carbon and a positive of a given diameter the P.D. required to send a given current through a fixed length of arc depends principally, if not entirely, on the nature of the surface of the crater, being greater or less according as the carbon of which this surface is composed is harder or softer.*

By the term 'area of the crater' is meant *the area of the mouth of the crater*, or, still more accurately, the plane area of that region of the end of the positive carbon which is sharply cut off from the rest by its peculiar brilliance and whiteness. The area of the soft carbon in the surface of the crater is taken to be the projection on the mouth of the crater of that area of the crater that is composed of soft carbon, and the proportion of soft carbon in the surface of the crater is measured by the ratio of the area of the soft carbon to the total area of the crater. This ratio for each current and length of arc will be called its '*soft crater ratio.*'

The ratio of the area of the hard carbon in the surface of the crater to the area of the crater will be called the '*hard crater ratio.*'

Arcs of Constant Length.

The area of the crater is known to increase as the current increases. With a constant length of arc, therefore, when the current is very small the whole of the crater will be in the core; as the current increases some hard carbon will be embraced by the crater, and the P.D. will therefore, by the hypothesis, be higher than if the whole crater were of soft carbon. The larger the current the greater will be the area of the crater, and consequently the greater will be the amount of hard carbon in its surface; there will be a tendency of the P.D. to rise on account of this increasing amount of hard carbon in the crater, which will struggle with its tendency to fall on account of the increase of the current. According as the one or other of these tendencies gets the upper hand, or as they exactly counterbalance one another, will the P.D. *increase*, *diminish*, or *remain stationary* as the current increases.

Constant Currents.

It has not hitherto been known how the area of the crater varied with the length of the arc. Hence a very good way of testing the accuracy of my hypothesis suggested itself. The hypothesis was used in conjunction with the curves connecting P.D. with length of arc for constant currents, to determine what *should* be the form of the curves connecting the area of the crater with the length of the arc when the current was constant. If these curves were the same as those obtained from actual measurements of the crater, the presumption would be that the

hypothesis was correct. The comparison was made with very satisfactory results, the form of the curves being exactly the same in both cases.

From the hypothesis and the curves connecting P.D. and length of arc for constant currents it was deduced that—

1. *When a cored positive carbon is used and a constant current is flowing the area of the crater must increase as the length of the arc increases.*
2. *The change that takes place in the ratio of the soft carbon to the total amount of carbon in the surface of the crater with a given change of length must diminish as the arc increases in length.*
3. *The change that takes place in the ratio of the soft carbon to the total amount of carbon in the surface of the crater with a given change of length must be smaller, and the rate of change must become more nearly constant for all lengths of arc as the value of the constant current increases.*

Remembering that the ratio of the area of soft carbon to the area of the crater is called the 'soft crater ratio,' these three conditions may be put thus:—

1. With a cored positive carbon, and with a constant current flowing, the area of the crater must *increase*, and consequently the soft crater ratio must *diminish* as the length of the arc increases.
2. The change of soft crater ratio with change of length must diminish as the length of the arc increases.
3. The change of soft crater ratio with change of length must be the smaller, and the rate of change must become the more nearly constant the larger the current.

To test the accuracy of these conclusions, and therefore of the hypothesis upon which they were founded, measurements of the crater, made on the enlarged image of the arc in 1893, were used. It was found that straight line laws were obtained in two ways: (1) by plotting the P.D. for each length of arc, with the corresponding area of the crater with various constant currents; (2) by plotting the current with the corresponding area of the crater with various constant lengths of arc. From these two sets of straight lines corrected areas of crater were obtained, from which the laws connecting the area of the crater and the soft crater ratio with the length of the arc could be seen more clearly than with the uncorrected areas of crater.

These laws were exactly what had been predicted. It was found that with a cored positive and solid negative carbon, and with a constant current flowing—

1. The area of the crater *did* increase, and consequently the soft crater ratio diminished as the length of the arc increased; and
2. The change of soft crater ratio with a given change of length *did* diminish as the length of the arc increased; and
3. The change of soft crater ratio with a given change of length *was* smaller, and the rate of change was more nearly constant the larger the current.

From the parallel straight lines connecting the area of the crater with the current for constant lengths of arc three facts were deduced, viz—

1. That with constant lengths of arc the *area of the crater*, minus a constant depending on the length of the arc, is proportional to the current.
2. That the *change of area of crater* with a given change of length of arc is independent of the value of the current flowing.
3. That the *change of area of crater* with a given change of current is independent of the length of the arc.

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10. *On the Source of Luminosity in the Electric Arc.* *By* H. Crew *and* O. H. Basquin.

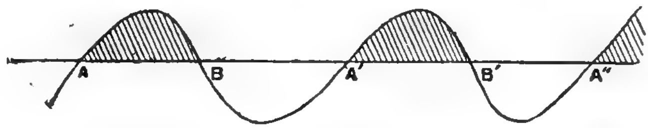
Three possible causes of luminosity were considered, viz. heat alone, chemical action, the electric current. The problem set was to determine the parts which thermal, chemical, and electric cause, respectively, plays in the electric arc.

Chemical effects were practically excluded by working the arc in an air-tight metallic hood, filled with a gas which exercised no chemical action upon the electrodes. An air-tight glass window in this hood enabled the observer to examine the arc either with the naked eye or with the spectroscope.

To exclude the electric current for an instant, and to examine the arc immediately afterwards, the following device was used:—

A high-speed, 100-volt, alternator was employed to feed the arc. But, in series with the armature and the arc, were placed two interrupters, which cut out either all the positive or all the negative parts of the alternating current. In

FIG. 1.

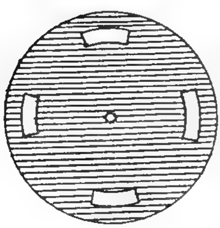


either case the current was broken just as the current curve crossed the axis of X. In case the positive currents were cut out, the *break* occurred at A, A′, A″, &c., the *make* at B, B′, &c., as indicated in the figure.

By cutting the current off just as the curve crosses the axis, self-induction effects are practically avoided.

The intervals of time indicated by the shaded portion of the current curve were employed to photograph the arc or to examine it with the eye. This examination was made through openings in a large steel disc of the form indicated in the figure. This occulting screen and the two large interrupter rings were placed on a common shaft with the armature of the dynamo.

FIG. 2.



The interrupter rings were insulated from the shaft; each had two slate sectors keyed into it, and each carried two brushes set 90° apart.

It was found that, in the case of the iron arc, in an atmosphere of air, oxygen, coal gas, or hydrogen, there are two distinct luminosities having very different properties.

Of these luminosities one is a cloud of light, strongly coloured with yellow, and floating at a distance of some millimeters from the electrodes, one of which was an iron rod, the other a rotating iron disc.

This is apparently the 'flame' of the ordinary carbon arc.

This yellow cloud persists from one one-hundredth to one two-hundredth of a second after the current has been broken.

The other luminosity is the blue sheet of light which most impresses the eye on looking at the ordinary iron arc.

This light disappears in less than one five-thousandth part of a second after the current is cut off. One is certain that the interval during which the blue light persists is, however, still less than this. For the actual instant at which the current is shut off is not the instant at which the brush passes on to the slate sector, but an instant later than this, on account of the spark which remains at break of current.

So that, after the arc is broken, practically the only light that remains is this yellow cloud.

The light from the red-hot iron poles, giving a continuous spectrum, is, of course, here *not* considered.

[Photographs of the two parts of the arc shown to the section.]

On making the current the first light to appear is an intense blue right at the point of contact of the two electrodes. The yellow cloud, the 'flame,' comes later. We have succeeded in photographing the blue arc of one current before the yellow cloud of a previous current had died out, thus obtaining the two kinds of arc on one plate *with a single exposure.*

In hydrogen the luminosity is very much less than in any of the other gases when the current has been shut off as long as one-thousandth of a second.

In oxygen the floating cloud is very brilliant. In coal gas it is barely visible, and of a decidedly reddish hue. In this case the interior of the hood is lined with a deposit of carbon. Query, Is this red light due to carbon incandescent at the moment of dissociation from the hydrogen?

The spectrum of the blue arc is the ordinary iron-arc spectrum.

The spectrum of the yellow cloud which persists is also a linear spectrum of iron; but the distribution of intensities among the lines is very different indeed from that of the ordinary iron arc. The investigation of the difference between these two spectra when separated in this way is a comparatively easy matter. This investigation is already under way.

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11. *On some New Forms of Gas Batteries and a New Carbon-consuming Battery.*[1] *By* WILLARD E. CASE.

In 1839 Grove announced his invention of the gas battery; he considered it the most simple arrangement to produce electricity, but not a practical way to generate electrical energy. He used platinum sponge or platinum black as the absorbent to facilitate the combination of the gases. The following experimental determinations by the author show, as far as they extend, that platinum or its compounds are not necessary to produce the combination of the gases in the production of electrical energy, so doing away with one of the most expensive drawbacks to the gas battery. The experiments also prove that carbon is oxidised to CO_2 at normal temperature without the application of heat, with the production of electrical energy.

The Chlorine-Carbon Cell.

A porous carbon tube-electrode, into which chlorine gas was passed, opposed to a carbon rod, which had been heated red hot, were placed in hydrochloric acid, of specific gravity 1·10. An E.M.F. of from 0·50 to 0·54 volt was obtained, depending on the condition of the carbons.

The carbon electrodes, after being heated, were placed in distilled water. With no chlorine gas passing through they had no difference of potential. When gas was passed into the carbon tube, at slightly above atmospheric pressure, the E.M.F. gradually increased to 0·44 of a volt at the end of twenty-six hours. On short circuit, 0·04 of an ampère was obtained, but it dropped rapidly to 0·02. The internal resistance was very high. The solution was analysed, and found to contain hydrochloric acid and carbon dioxide. The same experiment was repeated in a dark case, to see if the action took place in the absence of light. The chlorine gas was made in the dark and passed though the electrode. The electromotive force gradually increased, as in the first case, showing that the action took place in the dark.

A carbon electrode, through which chlorine was passed, and a negative platinum electrode opposed to it, in dilute hydrochloric acid, gave 0·40 of a volt, but the electromotive force did not hold up through the voltmeter circuit. Both electrodes were covered with gas after short-circuiting, and the E.M.F. dropped to 0·24 of a volt. On shaking the voltage jumped to 0·40.

A negative carbon electrode was substituted for the negative platinum. It had been heated red hot and was very porous, the surface soft and rough. The E.M.F. reached 0·58 of a volt, and gave on short circuit 1·24 ampère, but dropped slowly to 0·30. The negative carbon electrode was oxidised.

A platinum electrode in a paper envelope was opposed to powdered carbon in the bottom of a glass jar in hydrochloric acid, chlorine being passed into the solu-

[1] Published *in extenso* in the *Electrician*, Sept. 17, 1897, and in the *Electrical Engineer* (New York), Sept. 2, 1897.

tion near the platinum. An E.M.F. of 0·60 of a volt, and on short circuit 0·90 ampère, were obtained. The current remained fairly steady. The surface of each electrode was about forty-five square inches.

A cell made up as above, but with graphite instead of carbon, gave 0·54 of a volt, but dropped rapidly on short circuit, the graphite not oxidising fast enough to give a steady current.

A dense carbon rod opposed to powdered carbon gave 0·40 of a volt, and on short circuit 0·20 of an ampère. The rod was encased in filter paper to protect it from floating particles of powdered carbon, and the chlorine passed into the solution near it.

Two small glass beakers with a carbon rod in one and a platinum plate in the other, and containing hydrochloric acid, were connected by an inverted U tube. When chlorine was passed into the vessel with the platinum, an E.M.F. of 0·48 volt was obtained. When chlorine was passed into the beaker containing the carbon rod, an E.M.F. of 0·14 was obtained, but it dropped almost immediately to zero. When chlorine was passed into both beakers, no E.M.F. was obtained.

The chemical reaction of the chlorine-carbon cell was as follows:

$$H_2O + Cl_2 = 2HCl + O,$$

the oxygen of the decomposed water attacking the carbon, and hydrochloric acid and carbon dioxide being formed.

Carbon Monoxide-Chlorine Cell.

Cell made as follows: a glass tube, 2·25-inch bore and 6 inches long, corked at each end, with a porous tube, 1 inch outside diameter, passing through the glass tube and corks, and corked at each end; carbon rods and gas inlet and outlet tubes let into each chamber, which were filled with dry animal charcoal previously treated with hydrochloric acid. The porous tube was saturated with concentrated hydrochloric acid. Chlorine gas was passed through the outer tube. An E.M.F. of 0·18 volt was obtained. When carbon monoxide gas was passed through the inner tube the voltage increased to 0·33 volt. A slight increase of the pressure of the gases increased the voltage. The glass tube became hot. This reaction would produce carbon oxychloride.

Marsh Gas-Chlorine Cell.

Two carbon tube electrodes, three-fourths of an inch in diameter and four inches long, opposed to one another in a solution of hydrochloric acid, with chlorine passed into one and marsh gas into the other, gave an E.M.F. between 0·60 and 0·70 volt, varying with the condition of the carbon. A current of 0·70 ampère was obtained on short circuit, but the cell rapidly polarised. Afterwards fresh carbon electrodes, with the gases passing through them, were placed in distilled water, and the E.M.F. gradually increased from 0·00 to 0·14 in twelve hours. On testing the solution hydrochloric acid and carbon dioxide were found to be present. The chemical reaction of this cell is as follows:

$$CH_4 + 4Cl_2 + 2H_2O = CO_2 + 8HCl.$$

The calculated E.M.F. of this cell is 0·65 volt.

In these experiments it will be noted that platinum is not essential to the reactions. Both electrodes in each case can be carbon tubes or plates.

In making these determinations of electromotive force and current, a Weston direct-reading voltmeter and mil-ammeter were used. Resistance of voltmeter, 352 ohms, reading from 0·01 to 3·00 volts. The ammeter read from 0·01 to 2·00 ampères.

In all the experiments the gases used were but slightly above atmospheric pressure. Owing to limited time, the author is not able to furnish further data. Experiments to determine the many interesting questions involved are being conducted.

Mr. C. E. Timmerman, of Cornell University, has assisted the author in carrying out the experiments.

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12. *On the Determination of the State of Ionisation in Dilute Aqueous Solutions containing two Electrolytes. By* Professor J. G. MacGregor, *D.Sc., Dalhousie College, Halifax, N.S.*

The object of this communication is to draw attention to the possibility of determining, in some cases, what, according to the dissociation conception of electrolytic conduction, the coefficients of ionisation must be in the case of two electrolytes present in the same solution, the electrolytes either having, or not having, one ion in common, but being such as undergo no chemical change other than double decomposition.

When the two electrolytes (1 and 2) have one ion in common, they are the only electrolytes present in the solution. For determining the ionisation coefficients (a_1, a_2) we have then the following equations[1]:—(*a*) $a_1/V_1 = a_2/V_2$, where V_1, V_2 are the regional dilutions of 1 and 2, *i.e.* the quotients of the volumes of the regions of the solution which may be imagined to be occupied by 1 and 2 respectively, by the numbers N_1 and N_2 of gramme-equivalents of these electrolytes present, the equation being obtained from the conditions of kinetic equilibrium; (*b*) $N_1 V_1 + N_2 V_2 = v$, obtained from the equality of the volume (v) of the solution to the sum of the volumes of the regions referred to; (*c*) $a_1/V_1 = f_1 (V_1)$ and $a_2/V_2 = f_2 (V_2)$, the functions f_1 and f_2 being determined by means of measurements of the conductivity of simple solutions, the concentrations of ions in the regions occupied by the respective electrolytes being assumed to be the same as they would be in simple solutions of the same dilution. A mode of solving these equations by a graphical process is described in the papers cited above.

That the values of the ionisation coefficients obtained by solving these equations are those which the dissociation theory demands is borne out by the fact that, in the case of solutions containing NaCl and KCl (see papers cited above) or NaCl and[2] HCl, when these values are substituted in the expression of the dissociation theory for the conductivity of a complex solution, the calculated values agree with those observed within a fraction of 1 per cent.

The following results of the observations made on the above solutions, with respect to the relation of the ionisation in such solutions to the concentration, may be stated:—(1) In the case of dilute solutions (containing no more than about 0·5 grm.-equiv. per litre of either electrolyte), the rate at which the common concentration of ions increases with the concentration of either electrolyte is practically constant; (2) for solutions of greater concentration, this rate diminishes as the concentration of the solution with respect to either electrolyte increases.

When the electrolytes, 1 and 2, added to water in forming the solution, have no common ion, other two, 3 and 4, are formed by double decomposition, and there are thus four present in the solution. For determining the ionisation coefficients, we have then the following equations[3]:—(*a*) $a_1/V_1 = a_2/V_2 = a_3/V_3 = a_4/V_4$, and $N_1V_1 \cdot N_2V_2 = N_3V_3 \cdot N_4V_4$, obtained from the conditions of equilibrium; (*b*) $N_1V_1 + N_2V_2 + N_3V_3 + N_4V_4 = v$, from the volume relation; (*c*) $a_1/V_1 = f_1 (V_1)$, $a_2/V_2 = f_2 (V_2)$, &c., from the relation of concentration of ions to dilution, the V's having the same signification as above; and (*d*) from the conservation of mass, n_1 and n_2 being the numbers of grm.-equivalents of 1 and 2

[1] *Trans. N.S. Inst. Sci.*, 9, 101; *Phil. Mag.* [5], 41, 276 (1896).
[2] McIntosh, *Trans. N.S. Inst. Sci.*, 9, 120; *Phil. Mag.* [5], 41, 510 (1896).
[3] *Trans. Roy. Soc. Can.* [2], 2, Sec. III. 65 (1896).

added to water in forming the solution, $n_1 = N_1 + N_3$, $n_2 = N_2 + N_4$, $N_3 = N_4$. The solution of these equations, even by the aid of a graphical process, seems to require more accurate values of the conductivity of simple solutions than we possess. But with the measurements available, we may readily prepare a solution having any desired concentration of ions, and therefore having one of the electrolytes present with any desired degree of ionisation. For this purpose draw curves for simple solutions of 1, 2, 3, 4, giving the relation of concentration of ions to dilution. Read off from these curves the dilutions, V_1, V_2, &c., of simple solutions of 1, 2, 3, 4 respectively, having the desired common value of the concentration of ions. If simple solutions of these dilutions are mixed in proper proportions as to volume, there will be no change of ionisation on mixing. To find the proper proportions, select any arbitrary value, v_4, of the volume of 4 which is to be mixed with the others. It will contain $N_4 = v_4/V_4$ grm.-equivalents of 4. From equations (*d*) above we must have $N_3 = N_4$. Hence the volume of 3 to be mixed with the others will be $v_3 = V_3\, v_4/V_4$. Next select arbitrarily any value of v_2. Then from the second of equations (*a*) we have $v_1 = v_3\, v_4/v_2 = V_3\, v_4^2/V_4\, v_2$. The volumes of the simple solutions of dilutions V_1, V_2, V_3, V_4, which must be mixed, in order to form a complex solution having the desired concentration of ions, are thus known. The solution may therefore be prepared. Moreover, as the concentrations of the simple solutions and the volumes of them which are mixed are known, the numbers of grm.-equivalents of the four electrolytes present may be determined; and as the common concentration of ions and the dilutions are known, the ionisation coefficients may be determined. The conductivity of the solution may therefore be calculated.

That the values of the ionisation coefficients obtained in this way are those demanded by the dissociation theory is borne out in this case also by the agreement between the observed values of the conductivity of solutions of the kind under consideration and the values calculated by the aid of these coefficients. Mr. E. H. Archibald, working in my laboratory, has recently both observed (by Kohlrausch's method) and calculated the conductivities of solutions containing $NaCl$ and K_2SO_4, and therefore also KCl and Na_2SO_4. I am indebted to him for the following statement of his results so far as he has gone:—

Solution, 1 litre of which contains				Concentration of Ions	Conductivity		
NaCl grm.-equiv.	$\frac{1}{2}K_2SO_4$ grm.-equiv.	KCl grm.-equiv.	$\frac{1}{2}Na_2SO_4$ grm.-equiv.		Observed	Calculated	Difference per cent.
·2041	·1537	·1851	·1851	·4541	5217	5183	−0·65
·1158	·0971	·1091	·1091	·2878	3311	3288	−0·7
·1087	·0927	·1035	·1035	·2744	3160	3139	−0·7
·03683	·03241	·03549	·03550	·1039	1192	1188	−0·3
·03077	·02710	·02987	·02988	·0887	1047	1044	−0·3

These results go to show that the ionisation coefficients of the electrolytes in the above solutions have been fairly accurately determined. They are interesting in themselves also as showing that the dissociation theory enables us to calculate the conductivity of a solution containing two electrolytes with no common ion.

Department II.—General Physics.

1. *An Apparatus for Verifying the Law of Conservation of Energy in the Human Body. By* Professor W. O. Atwater *and* Professor E. B. Rosa.

The authors undertook their investigation at the Wesleyan University in 1892, under the patronage of the University and the Storrs Experiment Station of Connecticut. In 1894 the United States Department of Agriculture inaugurated an investigation of the foods and nutrition of the people of the United States, and appropriated some funds for the research. The investigation has been continued for five years, during which time the apparatus has been gradually developed to a comparatively high degree of perfection.

The general plan of the work is to determine the potential energy of the food eaten by the person under investigation, by burning samples in a bomb calorimeter; to analyse other samples and determine the chemical composition of the food; to analyse and burn samples of the waste products of the body; to measure the heat evolved by the subject and the mechanical work done; then to balance the total net energy taken into the body against the energy given off as heat and work.

The heat was measured by placing the person under investigation in a large calorimeter, especially designed and constructed for this work, where he was hermetically sealed, and where he lived for periods of from one to twelve days. The calorimeter was 7 feet long, 6 feet 4 inches high, and 4 feet wide. Its walls were double and made of sheet copper and sheet zinc, and this chamber was enclosed in concentric wooden walls, to shield the calorimeter from change in temperature without.

The two metal walls were maintained at exactly the same temperature, so that no heat was gained or lost through the walls, and the heat generated within was carried away by a stream of water flowing through a copper pipe, called an 'absorber.' Tests of the calorimeter were made by passing an electric current through a known resistance, and measuring the heat generated; and also by burning alcohol in a lamp and calculating, from the amount of alcohol burned, its composition, and the heat of combustion of pure alcohol determined by the bomb calorimeter, the amount of heat that should be given, and measuring the heat actually evolved by the respiration calorimeter. These tests showed that the calorimeter is a very accurate instrument.

This investigation is followed up with studies in the metabolism of matter and energy in the human body.

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2. *The Rate of the Decrease of the Intensity of Shrill Sounds with Time. By* A. Wilmer Duff, *Purdue University, Indiana.*

Stokes has investigated theoretically the effect of viscosity in dissipating the energy of vibration of shrill sounds, and also, in another paper, the effect of radiation. Rayleigh has extended his method to thermal conduction, and Kirchhoff has investigated the effect of both viscosity and conduction, arriving at results in agreement with the investigations of Stokes and Rayleigh. In the present Paper the question is for the first time approached experimentally.

The distance at which eight very shrill whistles sounded simultaneously under a definite pressure just become inaudible is observed, and also the distances at which they become inaudible when sounded in pairs. From these observations the modulus of decay of amplitude is found, and for the case of a note of vibration frequency of 10,600 the modulus of decay turns out to be ·66. Comparing this result with the theoretical investigations, the effect of radiation only is deduced, and hence a value of ·1485 is found for the constant in Newton's law of cooling in the case of air. These seem to be the only values ever found experimentally for the modulus of decay and for the Newtonian constant of radiation.

3. *A New Instrument for Measuring the Intensity of Sound.* *By* A. G. WEBSTER *and* B. F. SHARPE.

The instrument consists of a spherical resonator, to which is attached a thin glass diaphragm, the excursions of which are measured by the displacements of interference fringes in a Michelson interferometer. The diaphragm carries at its centre a small plane mirror about 4 mm. square, which is made the movable plane of the interferometer, there being besides two fixed glasses and one movable in a slide by a slow-motion screw. The apparatus is solidly fastened to a bronze base, and is completely enclosed by a felt-covered box, leaving exposed only the resonator with a hole opposite the diaphragm. The apparatus is adjusted so that the fringes are parallel and vertical, using first monochromatic and then white light. When a sound is made, the fringes become blurred, so as to disappear, and must accordingly be observed stroboscopically. Accordingly for the source of sound is chosen a tuning-fork electrically maintained, while the fringes, reduced by a horizontal slit to a line of points moving horizontally, are observed by a small telescope whose objective is carried by the prong of a second independently maintained tuning-fork vibrating synchronously with the source of sound, the lens moving vertically. The fringes are accordingly seen as inclined lines, the inclination of which is measured by a graduated circle and rotating cross-hair in the eyepiece. The excursion is proportional to the tangent of the angular displacement. This was found more convenient than counting the number of fringes displaced.

The chief difficulty after that of securing absolute freedom from extraneous noises is in maintaining the constancy of the source of sound. This was finally accomplished by making the break of the fork which interrupted the circuit for the source proper a large mercury surface, the controlling fork being placed upon a solid pier, and boxed in, so as to emit no sound. The source proper was a fork mechanically connected to a diaphragm mounted upon a spherical resonator, all being boxed in except a circular orifice in the resonator, so that the sound proceeded from a definite point. This could be moved about the room without the intensity changing.

Observations were made in the middle of the night. The following data will give an idea of the constancy of the conditions:—

w = width of one fringe in micrometer divisions.
h = vertical height of stroboscopic image.
a = angle of fringes with vertical.
I = intensity of sound.
t = time of observation.

t	w	h	a	I
H. M.			° ′	
1 15	·947	11·78	19 8	18·69
1 30	·950	11·81	19 52	19·06
1 50	·946	11·80	19 22	19·22
2 5	·924	11·81	19 37	20·72
2 25	·920	11·84	19 30	20·63
3 15	·945	11·77	19 22	19·27
3 25	·938	11·83	19 7	19·02
3 45	·923 (?)	11·79	18 22	18·02

In these observations the source was a fork of 256 complete vibrations, sounding as if rather gently bowed. Observations of the displacement for a certain steady pressure were made, and from observations on the inertia of parts of the apparatus it is intended to reduce them to absolute measure.

4. *Atmosphere in its Effects on Astronomical Research.* *By* PERCIVAL LOWELL.

In every astronomical observation the rays of light which give us our knowledge of things beyond the earth have to traverse three media—the air, the lens, and the eye. Though much attention has been given to the lens, and not a little to the observer, almost none has been paid to the atmosphere, which on investigation turns out to be the most important factor of the three.

For the purpose of applying and studying this neglected and practically unknown factor, the first work in which we owe to Professor W. H. Pickering at Arequipa, the Lowell Observatory was put up at Flagstaff, Arizona. The practical results on Mars, Venus, Mercury, Jupiter's Satellites, and Uranus were both surprising to observers generally and revolutionary of previous ideas of these bodies.

Mr. Douglas then discovered that the cause of bad seeing could itself be seen, and that it was due to distorting refraction produced by waves of condensation and rarefaction in the air currents, which waves could be rendered visible as shadow bands crossing the field of view. He determined the size of these waves, their respective refractive powers, and the kind, speed, direction, and height of the currents. He thus found (1) that the seeing depends upon the absence of certain currents; (2) that the effectiveness of the object glass depends upon the size of the waves prevailing at any given time and place; (3) that the visibilities of limb and detail are different; (4) that the noxious currents can already, more or less, be predicted.

To minimise the harmful currents is, therefore, the object from a practical point of view. To do this the locality must be as free as possible from moisture, since water vapour is an unsettling element, and be as little as possible subject to change of any kind. These conditions are best satisfied by a large oasis in the midst of a desert, which is the case at Flagstaff.

Lastly, there is an absolute test of seeing, due to the laws of light, which can and should be generally applied—the condition of the spurious disk and rings of a star seen through a telescope. The scale is as follows:—

Seeing 10.—Disk perfectly defined, rings the same, both motionless in field.

Seeing 9.—Disk perfectly defined, rings the same, both moving slightly together in field.

Seeing 8.—Disk well defined, rings complete but moving, no bodily motion.

Seeing 7.—Disk well defined, rings complete but moving, slight bodily motion.

Seeing 6.—Disk well defined, rings tolerably complete, some bodily motion.

Seeing 5.—Disk well defined, rings tolerably complete, bodily motion.

Seeing 4. Disk well defined, rings broken into lines and dots, more bodily motion.

Seeing 3.—Disk well defined, rings broken into lines and dots, much bodily motion.

Seeing 2.—Disk tolerably defined, no evidence of rings.

Seeing 1.—Disk and rings in one confused mass, motion, slight increase in size.

Seeing 0.—Disk and rings in one confused mass, violent motion, image greatly enlarged.

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5. *Automatic Operation of Eclipse Instruments.* *By* Professor DAVID P. TODD.

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6. *The Cause of the Semi-annual Inversions of the Type Solar Curve in the Terrestrial Magnetic Field.* *By* Professor FRANK H. BIGELOW, *U.S. Weather Bureau, Washington, D.C.*

This paper gives a brief outline of the computation leading to the type curve, the phenomenon of semi-annual inversion, and the explanation of the same. This conclusion is then used to criticise certain views of the origin of the diurnal and

secular variations of the magnetic needle, widely held, and to advocate another working theory which seems to harmonise the system of magnetic observations in a suitable manner.

7. *Observations at Toronto with Magnet Watch Integrator.* *By* Professor FRANK H. BIGELOW.

8. *The Yerkes Observatory.* *By* GEORGE E. HALE, Director.

The author gave an account of the buildings and instruments of the Yerkes Observatory, with a statement regarding the first observations made with the 40-inch telescope.

9. *The Effects of Tension and Quality of the Metal upon the Changes in Length produced in Iron Wires by Magnetisation.* *By* B. B. BRACKETT.

10. *On the Susceptibility of Diamagnetic and Weakly Magnetic Substances.* *By* A. P. WILLS.

In the paper the author describes in detail a new method, applicable in the experimental study of the magnetic properties of those substances in which the coefficient of magnetic susceptibility is very small, and either positive or negative.

The method is based upon the property which all bodies have to a greater or less degree—namely, that they experience a mechanical force when placed in a non-homogeneous magnetic field. This force acts to impel the body towards stronger or weaker parts of the field, according as the body is magnetic or diamagnetic.

By means of a large electromagnet a practically uniform field is obtained, at least sufficiently uniform to suit the purpose to which it is put. The magnet is so designed that the pole pieces face each other. They are prismatic in form, and the surfaces are about $1\frac{1}{2} \times 8$ cm., and there is a space of about $1\frac{1}{2}$ cm. between them. The long edges of the pole pieces are placed horizontally. The body to be investigated is made in the form of a thin slab. The dimensions of the slab are about $\frac{1}{2} \times 4\frac{1}{2} \times 8$ cm. It is suspended, by means of a long wire, from one end of the beam of a delicate balance, and with the $4\frac{1}{2}$ cm. edges horizontal and parallel to the pole faces and the 8 cm. edges vertical. The vertical direction is called Z; the horizontal direction parallel to the pole faces Y, and that perpendicular to the plane of these two X. The lower Z face of the slab is placed in the horizontal plane of symmetry of the pole pieces.

The conditions of symmetry show that there will be no mechanical force acting upon the slab save in the Z direction. The balance serves to determine this force, which is called P. Theoretical considerations show

$$P = \frac{\kappa A \mu_1}{2}(H^2 - H_0^2),$$

where A is the area of one of the Z surfaces, H is the strength of field at lower Z surface, H_0 that at upper Z surface, κ the coefficient of susceptibility, defined by

$$\kappa = \frac{1}{4\pi}\left(\frac{\mu_2 - \mu_1}{\mu_1}\right),$$

where μ_1 is permeability of air, and μ_2 that of slab. H_0^2 in comparison with H^2 is found in practice to be negligible. If μ_1 is put equal to unity, then

$$\kappa = \frac{2P}{AH^2}.$$

H is determined by measuring the force exerted by the field upon a conductor of known length when placed in the field at the proper position, and through which

a known current is flowing. For this purpose the same balance mentioned above is used.

A few of the numerous determinations of the susceptibility coefficients are given below. The middle column gives the field strengths at which the determinations are made.

Substance.	H	κ
Italian marble	8,080	$-\cdot945 \times 10^{-6}$
Optical glass	8,120	$-\cdot578 \times 10^{-6}$
White wax	8,220	$-\cdot560 \times 10^{-6}$
White wood	3,700	$-\cdot176 \times 10^{-6}$
Sulphur	8,220	$-\cdot765 \times 10^{-6}$

The question as to whether the coefficient κ is constant when the field strength H is varied is discussed. The following determinations were made upon bismuth.

Substance.	H	κ
Bismuth	1,640	$-12\cdot55 \times 10^{-6}$
Bismuth	3,680	$-12\cdot22 \times 10^{-6}$
Bismuth	8,220	$-12\cdot27 \times 10^{-6}$
Bismuth	8,830	$-12\cdot50 \times 10^{-6}$
Bismuth	10,490	$-12\cdot34 \times 10^{-6}$

11. *On Magnetic Periodicity as connected with Solar Physics. By* Arthur Harvey.

The author advances as a connected theory of solar physics that the sun's true body is within the envelope of which we see the surface; that it rotates more slowly than the luminous (photospheric) cloud-layer, from the spots on which the sun's rotation has been calculated; that spots and prominences are symptoms of disturbances which have their seats on the inner sun; that these loci of intense chemical action occupy large areas, and are intermittent and recurrent in their activity.

He reviews the arguments respecting periodicity in the cases of sun spots and of waves of heat and cold, and seeks to establish, from the records of magnetic observations at Toronto, beginning in 1841, that there is a periodicity in magnetic disturbances of 27·24575 days, which the author thinks is the synodical rotation period of the true body of the sun, with which the recurrences of sun spots, of solar protuberances, of hot and cold waves upon the earth, and other phenomena dependent on solar action must harmonise.

From thermal considerations Mr. Carlos Honoré, of Montevideo, arrives at a result almost identical with that of this paper.

WEDNESDAY, AUGUST 25.

The following Papers were read:—

1. *On the Refractivity of Certain Mixtures of Gases. By* Professor Ramsay, *F.R.S., and* Morris W. Travers.

The authors found that the refractivity of air being taken as unity, that of

Oxygen	was	0·9243
Nitrogen	„	1·0163
Argon	„	0·9596
Hydrogen	„	0·4733
Helium	„	0·1255

They investigated the ratio of the refractivities of oxygen, nitrogen, and argon, and compared them with that of air. It was found that the sum of the refrac-

tivities of the constituents, taken in the proportions in which they occur in air, differed from that of air by being 0·35 per cent. too small. Similar experiments made with a mixture of hydrogen and helium gave the result that the sum of the refractivities of these gases, taken separately, differed from that of the mixture by no less than 3 per cent. in excess. It is thus probable that gases are not without influence on each other, but that in some cases the refractivity is diminished, in others increased by mixture.

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2. *Note on the Use of the Trifilar Suspension in Physical Apparatus. By* SILVANUS P. THOMPSON, *F.R.S.*

The author advocated the use of trifilar suspensions in certain forms of apparatus, as having the advantage over bifilar in not being liable to be thrown into lateral pendular motion. He instanced the case of a differential D'Arsonval galvanometer, of a moment-of-inertia apparatus designed by Professor Dalby, and of an apparatus designed by himself for illustrating mechanically the transmission of transverse vibrations and of Hertz waves, in which model the part corresponding to the Hertz resonator (a metal ring) was hung by a trifilar suspension.

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3. *On Zeeman's Discovery of the Effects of Magnetism on Spectral Lines. By* Professor O. J. LODGE, *F.R.S.*

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4. *On the Use of a Constant Total Current Shunt with Ballistic Galvanometers. By* Professor W. E. AYRTON, *F.R.S., and* J. MATHER.

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5. *The Sensibility of Galvanometers. By* Professor W. E. AYRTON, *F.R.S., and* J. MATHER.

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6. *Short versus Long Galvanometers for Very Sensitive Zero Tests. By* Professor W. E. AYRTON, *F.R.S., and* J. MATHER.

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7. *On a Research in Thermo-electricity by means of a Platinum Resistance Pyrometer. By* H. M. TORY, *M.A., Lecturer in Mathematics and Demonstrator in Physics, McGill University, Montreal.*

[Communicated by Prof. H. L. CALLENDAR, M.A., F.R.S.]

The paper is an account of some experiments carried on in the McDonald Physics Building of McGill College, with a view to applying the electrical resistance pyrometer to the phenomena of thermo-electricity.

The method was suggested by Professor Callendar, whose work, with that of Messrs. Griffiths, Heycock, and Neville, has fairly well established the formulas for calculating temperature by this means.

The object of the investigation was to give a more rigid verification of Tait's parabolic formula.

The research, as conducted, naturally divides itself into three parts:—

1. The study of the usual form of copper-iron junction.
2. The study of a cast-iron wrought-iron junction. In conducting some experiments on the cyclical variation in the cylinder wall of a steam-engine, Professor Callendar found a couple of this type most suitable.
3. A direct comparison of the electrical resistance pyrometer with the platinum-platinum-rhodium couple.

In all cases the compensation method was used for measuring the E.M.F., the junction being balanced against a storage cell, which in turn was continuously balanced against a Clark cell kept at constant temperature. A carefully calibrated rheostat and a resistance box, both of the same material, were used.

The copper, cast-iron, and wrought-iron were tinned together at one end and heated in an oil bath, in which also was inserted the tube containing the pyrometer. The observations were taken only at perfectly steady temperatures. The direct reading galvanometer, devised by Professor Callendar for the purpose, was used in taking temperatures with the pyrometer. A carefully calibrated resistance box of the standard type was also used.

The platinum temperatures were calculated from the formula

$$pt = \left(\frac{R_t - R_0}{R_{100} - R_0}\right) 100 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the air thermometer temperatures by means of the difference formula

$$t - pt = \delta\left(\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right) \quad . \quad . \quad . \quad . \quad (2)$$

The object being to show the relation between the experimental curve and Tait's parabola, it is quite obvious that the ordinary method of plotting the temperature and the E.M.F. is not sufficient. A difference method similar to that above—equation (2)—was therefore adopted. The values of t were taken as abscissas, and the corresponding values $t - t_c$ as ordinates, t_c denoting the couple temperature, where $\frac{E_{100}}{100}$ is the temperature coefficient.

The relation to the parabolic formula may be shown thus:—

If

$$E_t = at + \beta t^2 \text{ (Tait's formula)}$$

then

$$t - t = \delta\left(\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right),$$

where δ is a constant depending on the nature of the metals. The value δ was calculated from the observed difference, $t - t$, at 200°. With this value for δ the parabola was plotted, passing therefore through three points on the experimental curve, those corresponding to 0°, 100°, and 200°. The accompanying curves show the differences from this parabola plotted along the axes.

In order to compare the Le Chatelier couple directly with the resistance pyrometer, the couple and the pyrometer were placed *in the same porcelain tube.* The couple was the usual form, a pure platinum wire coupled with another of platinum containing 10 per cent. rhodium. The wire was obtained from Messrs. Johnson, Matthey & Co. The junction was placed so as to be directly under the pyrometer coil, from which it was separated by strips of mica.

The temperatures, as before, were taken only at steady points. These points were obtained by varying the gas supply under a vessel containing molten tin, and by taking the melting point of tin, the boiling point of sulphur, and the melting point of silver. The curve in this case was also plotted against the parabola, the value δ being calculated from the observed difference of temperature, $t - t_c$, at 979°. The temperature coefficient of the junction was in this case taken as $\frac{E_{500}}{500}$, so as to give the nearest parabola throughout the whole range.

Curve I. shows the differences for the copper wrought-iron couple. The abscissas are temperatures by the air thermometer, the ordinates as before stated the differences from the parabola. The difference is $-1°{\cdot}1$ at 50° and about $+ 1°{\cdot}1$ at 150°.

If the temperature of the neutral point be calculated from the difference equation, using for δ the value found at 200, namely, 23·25, then T_0 (the neutral point) = 265°. The experimental curve shows it to be somewhat lower than this.

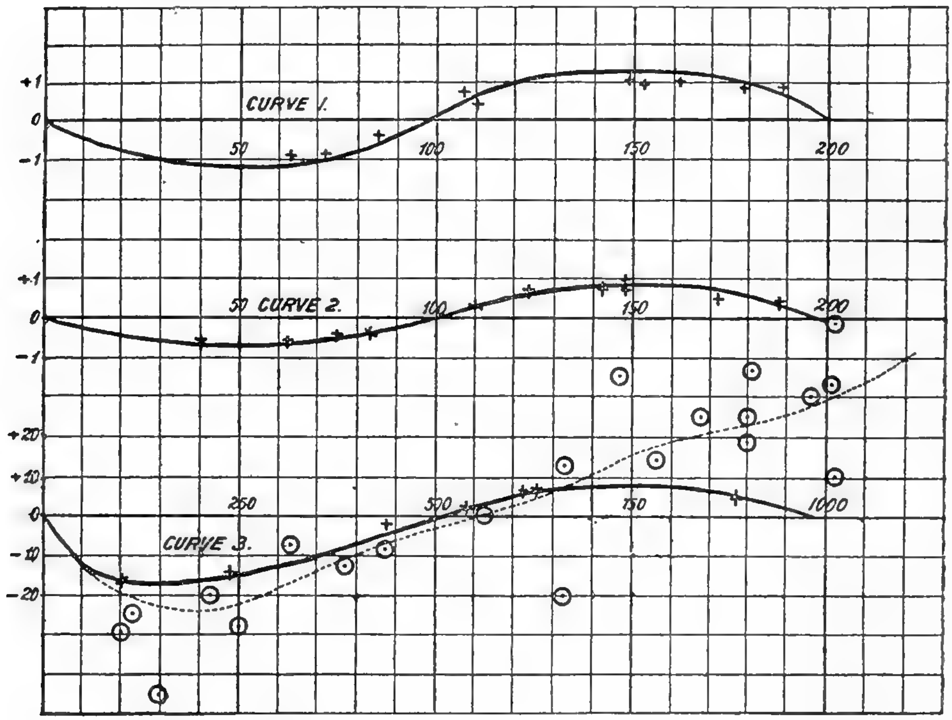
Curve II. shows on the same scale the differences for the junction of cast-iron and wrought-iron. The differences are smaller in this case, and the curve more regular. The neutral point, calculated as before, is 917°, which lies entirely beyond the limits of the experiments. The value of δ is 5·765.

By reference to the thermo-electric diagram it will be seen that the line for

cast-iron lies on the same side of the copper line as that of wrought-iron, but a little lower down.

Curve III. shows the differences as before for the platinum-platinum-rhodium couple. The scale here for the abscissas is just one-fifth that in the other two cases, and that of the ordinates one-tenth. The greatest difference will be seen to be at 150°, the differences being much greater below the 500° point than above.

Temperature by Thermocouple (Difference from Tait's Formula).



⊙ Observations of H. and W. + Observations by Plat. Pyr.

The curve representing the formula of Holborn and Wien [1] has been plotted, and the differences from the same parabola are shown by the dotted line. Their observations are necessarily much less accurate than those taken by the resistance pyrometer, as is shown by the points marked ⊙, along the difference curve. This is owing, in the first place, to the difficulties in air thermometry work, and also to the fact that the temperature was changing when the observations were taken. Their curve, though similar, shows the E.M.F. for the same difference of temperature to be considerably higher than in the present case, due probably to a difference in the composition of the alloy. Various other empirical formulæ have been suggested, but as they have no theoretical basis, they have not been considered. It is obvious that a straight line does not fulfil the conditions unless it be between points not very far separated.

Tait's formula, as far as it holds, perhaps simply amounts to drawing the nearest parabola, as the differences found in the present observations are quite beyond the limits of possible experimental errors. There seems to be no reason, however, to conclude that the formula may not represent the physical explanation of the effect, at least to a first approximation.

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[1] *Wied. Ann.*, 1892, p. 107.

8. *On a Simple Modification of the Board of Trade Form of the Standard Clark Cell. By* H. L. CALLENDAR, *M.A., F.R.S., Professor of Physics, and* H. T. BARNES, *M.A.Sc., Demonstrator of Physics, of McGill University, Montreal.*

The authors have been engaged for some years past in experiments on the variation of E.M.F. of the Clark cell under the most exacting conditions of temperature change. They have studied the behaviour of various types of the cell, and have recently devised a very simple form, in many respects closely resembling that described in the Board of Trade Memorandum, but somewhat easier to construct, and also entirely free from diffusion-lag in the changes of its E.M.F. consequent on the most sudden variations of temperature.

The cell is set up in a test-tube, but the materials are filled in the inverse of the usual order. First zinc amalgam, to which connection is made by means of a wire sealed into a glass tube. Next a layer of crystals of zinc sulphate, followed by a layer of paste of mercurous sulphate prepared in the usual manner, in which is coiled a fine amalgamated platinum wire, which serves in place of the mercury. The whole is sealed either with a cork and marine glue, or better hermetically, by sealing the glass tube on to the platinum electrodes.

With this method of construction, both the elements are always in contact with crystals, and there can be no diffusion-lag. The cells are at least equal to the H form in this respect, and are much easier to make, and more convenient to use, especially for immersion in a water-bath.

The same method of construction has also been applied with success to the cadmium cell. These cells appear to be as reliable as the Clark cells at temperatures above 10° C., but the E.M.F. is dependent upon the proportions of the amalgam. Below 10° C., there appear to be two possible rates of variation of the E.M.F., corresponding to different hydrates, as shown in a recent communication to the Royal Society to be the case with the Clark cell between the temperatures 30° and 50°.

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9. *On the Cyclical Variation with Temperature of the E.M.F. of the H Form of Clark's Cell. By* F. S. SPIERS, F. TWYMAN, *and* W. L. WATERS.

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10. *On the Disruptive Discharge in Air and Dielectric Liquids. By* T. W. EDMONDSON.

The object of the experiments described was to determine, if possible, the relation existing between the spark-length and the potential at which the disruptive discharge takes place in air and a number of insulating oils, when the electrodes used are spheres. The measurements in air were made by direct readings of a guard-ring electrometer and a spark micrometer, connected in parallel with a Wimshurst machine.

The curves for air, in which the ordinates represent potential differences, and the abscissas the corresponding spark-lengths, are found to be hyperbolic and are represented by equations of the form—

$$V^2 = ad + bd^2,$$

where V is given in C.G.S. units and d in millimetres.

The values of a and b obtained were—

Diam. of Spheres in Cm.	a	b
·5	235·14	83·25
1·0	186·36	99·42
2·0	144·41	114·49
3·0	49·42	144·71

The differences between the calculated and observed values of V are in general, not more than 1 per cent., and there is also good agreement with the results previously obtained by Baille, Bichat and Blondlot, Paschen and Freyberg.

In the case of the insulating oils it was found impracticable to make direct readings, on account of the dense deposit of carbon on the electrodes, which materially altered the conditions of the discharge.

The method of Macfarlane and Pierce was therefore adopted, and a pair of spheres of 1 cm. diam. were used as a subsidiary electrometer, the results previously obtained being used for the reduction of the results now obtained. At high potentials it was found impossible to get a consistent set of readings, on account of the violent agitation of the liquid, especially in the case of the lighter oils, like kerosene, in which the convection effects were very pronounced.

It was found that, while a smaller difference of potential is necessary to produce a discharge through a given distance for large spheres than for small ones, when they are close together, for longer distances the air is dielectrically stronger for large than for small spheres. For spark-lengths of more than 3 mm. the curves are practically straight, and the dielectric strength is therefore constant.

The values of the dielectric strength of air, at ordinary pressures, are as follows:—

Diam. of Spheres in Cm.	Dielectric Strength. C.G.S. Units per Cm.	Dielectric Strength. Kilovolts per Cm.
·5	95	28·5
1·0	102	30·6
2·0	108	32·4
3·0	120	36·0

All of these values are considerably higher than that obtained by Macfarlane for planes, viz. 23·8 kilovolts per cm.

The results for the insulating oils are not as uniform as those for air, but the same general characteristics were found, except in a few cases. In all cases the curves for the spheres of 3 cm. diam. are fairly straight, and it would appear that Macfarlane's conclusion that the dielectric strength of liquids is constant for plane electrodes is warranted.

The following estimates for the dielectric strength of the oils experimented upon are given:—

—	C.G.S. Units per Cm.	Kilovolts per Cm.
Kerosene	372	112
Water white distillate	528	108
Paraffin oil	422	127
Export distillate	319	96
Natural sperm oil	201	60
Mineral sperm oil	231	69
Raw linseed oil	223	67
Boiled linseed oil	222	67
Olive oil	169	51
Neatsfoot oil	172	52
Castor oil	347	104
Lard oil	90	27
Turpentine	233	70
Xylol	164	49

In the experiments with the alternating current the source of potential was a large induction coil, through the primary of which an alternating current of E.M.F. 50 volts and frequency 125 was passed, the electrometer and the spark micrometer being connected in parallel with the secondary of the coil. A variable resistance was used to regulate the potential. The results were not very satisfactory, but the values of the spark-length for the largest spheres were situated between those obtained by Steinmetz and Siemens, the frequencies of the alternating currents used by them being respectively 150 and 100. In fact the results appear to bear out Taumann's contention that the more rapidly the potential is changed the less will be the potential required to spark across any given distance.

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION.—Professor W. RAMSAY, PH.D., F.R.S.

THURSDAY, AUGUST 19.

The President delivered the following Address:—

An Undiscovered Gas.

A SECTIONAL address to members of the British Association falls under one of three heads. It may be historical, or actual, or prophetic; it may refer to the past, the present, or the future. In many cases, indeed in all, this classification overlaps. Your former Presidents have given sometimes a historical introduction, followed by an account of the actual state of some branch of our science, and, though rarely, concluding with prophetic remarks. To those who have an affection for the past, the historical side appeals forcibly; to the practical man, and to the investigator engaged in research, the actual, perhaps, presents more charm; while to the general public, to whom novelty is often more of an attraction than truth, the prophetic aspect excites most interest. In this address I must endeavour to tickle all palates; and perhaps I may be excused if I take this opportunity of indulging in the dangerous luxury of prophecy, a luxury which the managers of scientific journals do not often permit their readers to taste.

The subject of my remarks to-day is a new gas. I shall describe to you later its curious properties; but it would be unfair not to put you at once in possession of the knowledge of its most remarkable property—it has not yet been discovered. As it is still unborn, it has not yet been named. The naming of a new element is no easy matter. For there are only twenty-six letters in our alphabet, and there are already over seventy elements. To select a name expressible by a symbol which has not already been claimed for one of the known elements is difficult, and the difficulty is enhanced when it is at the same time required to select a name which shall be descriptive of the properties (or want of properties) of the element.

It is now my task to bring before you the evidence for the existence of this undiscovered element.

It was noticed by Döbereiner, as long ago as 1817, that certain elements could be arranged in groups of three. The choice of the elements selected to form these triads was made on account of their analogous properties, and on the sequence of their atomic weights, which had at that time only recently been discovered. Thus calcium, strontium, and barium formed such a group; their oxides, lime, strontia, and baryta are all easily slaked, combining with water to form soluble lime-water, strontia-water, and baryta-water. Their sulphates are all sparingly soluble, and resemblance had been noticed between their respective chlorides and between their nitrates. Regularity was also displayed by their atomic weights. The numbers then accepted were 20, 42·5 and 65; and the atomic weight of strontium, 42·5, is

the arithmetical mean of those of the other two elements, for $(65+20)/2=42{\cdot}5$. The existence of other similar groups of three was pointed out by Döbereiner, and such groups became known as 'Döbereiner's triads.'

Another method of classifying the elements, also depending on their atomic weights, was suggested by Pettenkofer, and afterwards elaborated by Kremers, Gladstone, and Cooke. It consisted in seeking for some expression which would represent the differences between the atomic weights of certain allied elements. Thus, the difference between the atomic weight of lithium, 7, and sodium, 23, is 16; and between that of sodium and of potassium, 39, is also 16. The regularity is not always so conspicuous; Dumas, in 1857, contrived a somewhat complicated expression which, to some extent, exhibited regularity in the atomic weights of fluorine, chlorine, bromine, and iodine; and also of nitrogen, phosphorus, arsenic, antimony and bismuth.

The upshot of these efforts to discover regularity was that, in 1864, Mr. John Newlands, having arranged the elements in eight groups, found that when placed in the order of their atomic weights, 'the eighth element, starting from a given one, is a kind of repetition of the first, like the eighth note of an octave in music.' To this regularity he gave the name 'The Law of Octaves.'

The development of this idea, as all chemists know, was due to the late Professor Lothar Meyer, of Tübingen, and to Professor Mendeléeff, of St. Petersburg. It is generally known as the 'Periodic Law.' One of the simplest methods of showing this arrangement is by means of a cylinder divided into eight segments by lines drawn parallel to its axis; a spiral line is then traced round the cylinder, which will, of course, be cut by these lines eight times at each revolution. Holding the cylinder vertically, the name and atomic weight of an element is written at each intersection of the spiral with a vertical line, following the numerical order of the atomic weights. It will be found, according to Lothar Meyer and Mendeléeff, that the elements grouped down each of the vertical lines form a natural class; they possess similar properties, form similar compounds, and exhibit a graded relationship between their densities, melting-points, and many of their other properties. One of these vertical columns, however, differs from the others, inasmuch as on it there are three groups, each consisting of three elements with approximately equal atomic weights. The elements in question are iron, cobalt, and nickel; palladium, rhodium, and ruthenium; and platinum, iridium, and osmium. There is apparently room for a fourth group of three elements in this column, and it may be a fifth. And the discovery of such a group is not unlikely, for when this table was first drawn up Professor Mendeléeff drew attention to certain gaps, which have since been filled up by the discovery of gallium, germanium, and others.

The discovery of argon at once raised the curiosity of Lord Rayleigh and myself as to its position in this table. With a density of nearly 20, if a diatomic gas, like oxygen and nitrogen, it would follow fluorine in the periodic table; and our first idea was that argon was probably a mixture of three gases, all of which possessed nearly the same atomic weights, like iron, cobalt, and nickel. Indeed, their names were suggested, on this supposition, with patriotic bias, as Anglium, Scotium, and Hibernium! But when the ratio of its specific heats had, at least in our opinion, unmistakably shown that it was molecularly monatomic, and not diatomic, as at first conjectured, it was necessary to believe that its atomic weight was 40, and not 20, and that it followed chlorine in the atomic table, and not fluorine. But here arises a difficulty. The atomic weight of chlorine is 35·5, and that of potassium, the next element in order in the table, is 39·1; and that of argon, 40, follows, and does not precede, that of potassium, as it might be expected to do. It still remains possible that argon, instead of consisting wholly of monatomic molecules, may contain a small percentage of diatomic molecules; but the evidence in favour of this supposition is, in my opinion, far from strong. Another possibility is that argon, as at first conjectured, may consist of a mixture of more than one element; but, unless the atomic weight of one of the elements in the supposed mixture is very high, say 82, the case is not bettered, for one of the elements in the supposed trio would still have a higher atomic weight than

potassium. And very careful experiments, carried out by Dr. Norman Collie and myself, on the fractional diffusion of argon, have disproved the existence of any such element with high atomic weight in argon, and, indeed, have practically demonstrated that argon is a simple substance, and not a mixture.

The discovery of helium has thrown a new light on this subject. Helium, it will be remembered, is evolved on heating certain minerals, notably those containing uranium; although it appears to be contained in others in which uranium is not present, except in traces. Among these minerals are clèveite, monazite, fergusonite, and a host of similar complex mixtures, all containing rare elements, such as niobium, tantalum, yttrium, cerium, &c. The spectrum of helium is characterised by a remarkably brilliant yellow line, which had been observed as long ago as 1868 by Professors Frankland and Lockyer in the spectrum of the sun's chromosphere, and named 'helium' at that early date.

The density of helium proved to be very close to 2·0, and, like argon, the ratio of its specific heats showed that it, too, was a monatomic gas. Its atomic weight therefore is identical with its molecular weight, viz., 4·0, and its place in the periodic table is between hydrogen and lithium, the atomic weight of which is 7·0.

The difference between the atomic weights of helium and argon is thus 36, or 40 − 4. Now there are several cases of such a difference. For instance, in the group the first member of which is fluorine we have—

Fluorine	19	16·5
Chlorine	35·5	19·5
Manganese	55	

In the oxygen group—

Oxygen	16	16
Sulphur	32	20·3
Chromium	52·3	

In the nitrogen group—

Nitrogen	14	17
Phosphorus	31	20·4
Vanadium	51·4	

And in the carbon group—

Carbon	12	16·3
Silicon	28·3	19·8
Titanium	48·1	

These instances suffice to show that approximately the differences are 16 and 20 between consecutive members of the corresponding groups of elements. The total differences between the extreme members of the short series mentioned are—

Manganese − Fluorine	36
Chromium − Oxygen	36·3
Vanadium − Nitrogen	37·4
Titanium − Carbon	36 1

This is approximately the difference between the atomic weights of helium and argon, 36.

There should, therefore, be an undiscovered element between helium and argon, with an atomic weight 16 units higher than that of helium, and 20 units lower than that of argon, namely 20. And if this unknown element, like helium and argon, should prove to consist of monatomic molecules, then its density should be half its atomic weight, 10. And pushing the analogy still farther, it is to be expected that this element should be as indifferent to union with other elements as the two allied elements.

My assistant, Mr. Morris Travers, has indefatigably aided me in a search for this unknown gas. There is a proverb about looking for a needle in a haystack; modern science, with the aid of suitable magnetic appliances, would, if the reward were sufficient, make short work of that proverbial needle. But here is a supposed unknown gas, endowed no doubt with negative properties, and the whole world to find it in. Still, the attempt had to be made.

We first directed our attention to the sources of helium—minerals. Almost every mineral which we could obtain was heated in a vacuum, and the gas which was evolved examined. The results are interesting. Most minerals give off gas when heated, and the gas contains, as a rule, a considerable amount of hydrogen, mixed with carbonic acid, questionable traces of nitrogen, and carbonic oxide. Many of the minerals, in addition, gave helium, which proved to be widely distributed, though only in minute proportions. One mineral—malacone—gave appreciable quantities of argon; and it is noteworthy that argon was not found except in it (and, curiously, in much larger amount than helium), and in a specimen of meteoric iron. Other specimens of meteoric iron were examined, but were found to contain mainly hydrogen, with no trace of either argon or helium. It is probable that the sources of meteorites might be traced in this manner, and that each could be relegated to its particular swarm.

Among the minerals examined was one to which our attention had been directed by Professor Lockyer, named eliasite, from which he said that he had extracted a gas in which he had observed spectrum lines foreign to helium. He was kind enough to furnish us with a specimen of this mineral, which is exceedingly rare, but the sample which we tested contained nothing but undoubted helium.

During a trip to Iceland in 1895, I collected some gas from the boiling springs there; it consisted, for the most part, of air, but contained somewhat more argon than is usually dissolved when air is shaken with water. In the spring of 1896 Mr. Travers and I made a trip to the Pyrenees to collect gas from the mineral springs of Cauterets, to which our attention had been directed by Dr. Bouchard, who pointed out that these gases are rich in helium. We examined a number of samples from the various springs, and confirmed Dr. Bouchard's results, but there was no sign of any unknown lines in the spectrum of these gases. Our quest was in vain.

We must now turn to another aspect of the subject. Shortly after the discovery of helium, its spectrum was very carefully examined by Professors Runge and Paschen, the renowned spectroscopists. The spectrum was photographed, special attention being paid to the invisible portions, termed the 'ultra-violet' and 'infra-red.' The lines thus registered were found to have a harmonic relation to each other. They admitted of division into two sets, each complete in itself. Now, a similar process had been applied to the spectrum of lithium and to that of sodium, and the spectra of these elements gave only one series each. Hence, Professors Runge and Paschen concluded that the gas, to which the provisional name of helium had been given, was, in reality, a mixture of two gases, closely resembling each other in properties. As we know no other elements with atomic weights between those of hydrogen and lithium, there is no chemical evidence either for or against this supposition. Professor Runge supposed that he had obtained evidence of the separation of these imagined elements from each other by means of diffusion; but Mr. Travers and I pointed out that the same alteration of spectrum, which was apparently produced by diffusion, could also be caused by altering the pressure of the gas in the vacuum tube; and shortly after Professor Runge acknowledged his mistake.

These considerations, however, made it desirable to subject helium to systematic diffusion, in the same way as argon had been tried. The experiments were carried out in the summer of 1896 by Dr. Collie and myself. The result was encouraging. It was found possible to separate helium into two portions of different rates of diffusion, and consequently of different density by this means. The limits of separation, however, were not very great. On the one hand, we obtained gas of a density close on 2·0; and on the other, a sample of density 2·4

or thereabouts. The difficulty was increased by the curious behaviour, which we have often had occasion to confirm, that helium possesses a rate of diffusion too rapid for its density. Thus, the density of the lightest portion of the diffused gas, calculated from its rate of diffusion, was 1·874; but this corresponds to a real density of about 2·0. After our paper, giving an account of these experiments, had been published, a German investigator, Herr A. Hagenbach, repeated our work and confirmed our results.

The two samples of gas of different density differ also in other properties. Different transparent substances differ in the rate at which they allow light to pass through them. Thus, light travels through water at a much slower rate than through air, and at a slower rate through air than through hydrogen. Now Lord Rayleigh found that helium offers less opposition to the passage of light than any other substance does, and the heavier of the two portions into which helium had been split offered more opposition than the lighter portion. And the retardation of the light, unlike what has usually been observed, was nearly proportional to the densities of the samples. The spectrum of these two samples did not differ in the minutest particular; therefore it did not appear quite out of the question to hazard the speculation that the process of diffusion was instrumental, not necessarily in separating two kinds of gas from each other, but actually in removing light molecules of the same kind from heavy molecules. This idea is not new. It had been advanced by Prof. Schützenberger (whose recent death all chemists have to deplore), and later, by Mr. Crookes, that what we term the atomic weight of an element is a mean; that when we say that the atomic weight of oxygen is 16, we merely state that the average atomic weight is 16; and it is not inconceivable that a certain number of molecules have a weight somewhat higher than 32, while a certain number have a lower weight.

We therefore thought it necessary to test this question by direct experiment with some known gas; and we chose nitrogen, as a good material with which to test the point. A much larger and more convenient apparatus for diffusing gases was built by Mr. Travers and myself, and a set of systematic diffusions of nitrogen was carried out. After thirty rounds, corresponding to 180 diffusions, the density of the nitrogen was unaltered, and that of the portion which should have diffused most slowly, had there been any difference in rate, was identical with that of the most quickly diffusing portion—*i.e.*, with that of the portion which passed first through the porous plug. This attempt, therefore, was unsuccessful; but it was worth carrying out, for it is now certain that it is not possible to separate a gas of undoubted chemical unity into portions of different density by diffusion. And these experiments rendered it exceedingly improbable that the difference in density of the two fractions of helium was due to separation of light molecules of helium from heavy molecules.

The apparatus used for diffusion had a capacity of about two litres. It was filled with helium, and the operation of diffusion was carried through thirty times. There were six reservoirs, each full of gas, and each was separated into two by diffusion. To the heavier portion of one lot, the lighter portion of the next was added, and in this manner all six reservoirs were successively passed through the diffusion apparatus. This process was carried out thirty times, each of the six reservoirs having had its gas diffused each time, thus involving 180 diffusions. After this process, the density of the more quickly diffusing gas was reduced to 2·02, while that of the less quickly diffusing had increased to 2·27. The light portion on re-diffusion hardly altered in density, while the heavier portion, when divided into three portions by diffusion, showed a considerable difference in density between the first third and the last third. A similar set of operations was carried out with a fresh quantity of helium, in order to accumulate enough gas to obtain a sufficient quantity for a second series of diffusions. The more quickly diffusing portions of both gases were mixed and rediffused. The density of the lightest portion of these gases was 1·98; and after other 15 diffusions, the density of the lightest portion had not decreased. The end had been reached; it was not possible to obtain a lighter portion by diffusion. The density of the main body of this gas is therefore 1·98; and its refractivity, air being taken as unity, is

0·1245. The spectrum of this portion does not differ in any respect from the usual spectrum of helium.

As re-diffusion does not alter the density or the refractivity of this gas, it is right to suppose that either one definite element has now been isolated; or that if there are more elements than one present, they possess the same, or very nearly the same, density and refractivity. There may be a group of elements, say three, like iron, cobalt, and nickel; but there is no proof that this idea is correct, and the simplicity of the spectrum would be an argument against such a supposition. This substance, forming by far the larger part of the whole amount of the gas, must, in the present state of our knowledge, be regarded as pure helium.

On the other hand, the heavier residue is easily altered in density by re-diffusion, and this would imply that it consists of a small quantity of a heavy gas mixed with a large quantity of the light gas. Repeated re-diffusion convinced us that there was only a very small amount of the heavy gas present in the mixture. The portion which contained the largest amount of heavy gas was found to have the density 2·275, and its refractive index was found to be 0·1333. On re-diffusing this portion of gas until only a trace sufficient to fill a Plücker's tube was left, and then examining the spectrum, no unknown lines could be detected, but, on interposing a jar and spark gap, the well-known blue lines of argon became visible; and even without the jar the red lines of argon, and the two green groups were distinctly visible. The amount of argon present, calculated from the density, was 1·64 per cent., and from the refractivity 1·14 per cent. The conclusion had therefore to be drawn that the heavy constituent of helium, as it comes off the minerals containing it, is nothing new, but, so far as can be made out, merely a small amount of argon.

If, then, there is a new gas in what is generally termed helium, it is mixed with argon, and it must be present in extremely minute traces. As neither helium nor argon has been induced to form compounds, there does not appear to be any method, other than diffusion, for isolating such a gas, if it exists, and that method has failed in our hands to give any evidence of the existence of such a gas. It by no means follows that the gas does not exist; the only conclusion to be drawn is that we have not yet stumbled on the material which contains it. In fact, the haystack is too large and the needle too inconspicuous. Reference to the periodic table will show that between the elements aluminium and indium there occurs gallium, a substance occurring only in the minutest amount on the earth's surface; and following silicon, and preceding tin, appears the element germanium, a body which has as yet been recognised only in one of the rarest of minerals, argyrodite. Now, the amount of helium in fergusonite, one of the minerals which yields it in reasonable quantity, is only 33 parts by weight in 100,000 of the mineral; and it is not improbable that some other mineral may contain the new gas in even more minute proportion. If, however, it is accompanied in its still undiscovered source by argon and helium, it will be a work of extreme difficulty to effect a separation from these gases.

In these remarks it has been assumed that the new gas will resemble argon and helium in being indifferent to the action of reagents, and in not forming compounds. This supposition is worth examining. In considering it, the analogy with other elements is all that we have to guide us.

We have already paid some attention to several triads of elements. We have seen that the differences in atomic weights between the elements fluorine and manganese, oxygen and chromium, nitrogen and vanadium, carbon and titanium, are in each case approximately the same as that between helium and argon, viz., 36. If elements further back in the periodic table be examined, it is to be noticed that the differences grow less, the smaller the atomic weights. Thus, between boron and scandium, the difference is 33; between beryllium (glucinum) and calcium, 31; and between lithium and potassium, 32. At the same time, we may remark that the elements grow liker each other, the lower the atomic weights. Now, helium and argon are very like each other in physical properties. It may be fairly concluded, I think, that in so far they justify their position. Moreover, the pair of elements which show the smallest difference between their atomic weights

is beryllium and calcium; there is a somewhat greater difference between lithium and potassium. And it is in accordance with this fragment of regularity that helium and argon show a greater difference. Then again, sodium, the middle element of the lithium triad, is very similar in properties both to lithium and potassium; and we might, therefore, expect that the unknown element of the helium series should closely resemble both helium and argon.

Leaving now the consideration of the new element, let us turn our attention to the more general question of the atomic weight of argon, and its anomalous position in the periodic scheme of the elements. The apparent difficulty is this: The atomic weight of argon is 40; it has no power to form compounds, and thus possesses no valency; it must follow chlorine in the periodic table, and precede potassium; but its atomic weight is greater than that of potassium, whereas it is generally contended that the elements should follow each other in the order of their atomic weights. If this contention is correct, argon should have an atomic weight smaller than 40.

Let us examine this contention. Taking the first row of elements, we have:

$$\mathrm{Li}=7,\ \mathrm{Be}=9{\cdot}8,\ \mathrm{B}=11,\ \mathrm{C}=12,\ \mathrm{N}=14,\ \mathrm{O}=16,\ \mathrm{F}=19,\ ?=20.$$

The differences are:

$$2{\cdot}8,\ 1{\cdot}2,\ 1{\cdot}0,\ 2{\cdot}0,\ 2{\cdot}0,\ 3{\cdot}0,\ 1{\cdot}0.$$

It is obvious that they are irregular. The next row shows similar irregularities. Thus:

$$(?=20),\ \mathrm{Na}=23,\ \mathrm{Mg}=24{\cdot}3,\ \mathrm{Al}=27,\ \mathrm{Si}=28,\ \mathrm{P}=31,\ \mathrm{S}=32,\ \mathrm{Cl}=35{\cdot}5,\ \mathrm{A}=40.$$

And the differences:

$$3{\cdot}0,\ 1{\cdot}3,\ 2{\cdot}7,\ 1{\cdot}0,\ 3{\cdot}0,\ 1{\cdot}0,\ 3{\cdot}5,\ 4{\cdot}5.$$

The same irregularity might be illustrated by a consideration of each succeeding row. Between argon and the next in order, potassium, there is a difference of $-0{\cdot}9$; that is to say, argon has a higher atomic weight than potassium by 0·9 unit; whereas it might be expected to have a lower one, seeing that potassium follows argon in the table. Farther on in the table there is a similar discrepancy. The row is as follows:

$$\mathrm{Ag}=108,\ \mathrm{Cd}=112,\ \mathrm{In}=114,\ \mathrm{Sn}=119,\ \mathrm{Sb}=120{\cdot}5,\ \mathrm{Te}=127{\cdot}7,\ \mathrm{I}=127.$$

The differences are:—

$$4{\cdot}0,\ 2{\cdot}0,\ 5{\cdot}0,\ 1{\cdot}5,\ 7{\cdot}2,\ -0{\cdot}7.$$

Here, again, there is a negative difference between tellurium and iodine. And this apparent discrepancy has led to many and careful redeterminations of the atomic weight of tellurium. Professor Brauner, indeed, has submitted tellurium to methodical fractionation, with no positive results. All the recent determinations of its atomic weight give practically the same number, 127·7.

Again, there have been almost innumerable attempts to reduce the differences between the atomic weights to regularity, by contriving some formula which will express the numbers which represent the atomic weights, with all their irregularities. Needless to say, such attempts have in no case been successful. Apparent success is always attained at the expense of accuracy, and the numbers reproduced are not those accepted as the true atomic weights. Such attempts, in my opinion, are futile. Still, the human mind does not rest contented in merely chronicling such an irregularity; it strives to understand why such an irregularity should exist. And, in connection with this, there are two matters which call for our consideration. These are: Does some circumstance modify these 'combining proportions' which we term 'atomic weights'? And is there any reason to suppose that we can modify them at our will? Are they true 'constants of Nature,' unchange-

able, and once for all determined? Or are they constant merely so long as other circumstances, a change in which would modify them, remain unchanged?

In order to understand the real scope of such questions, it is necessary to consider the relation of the 'atomic weights' to other magnitudes, and especially to the important quantity termed 'energy.'

It is known that energy manifests itself under different forms, and that one form of energy is quantitatively convertible into another form, without loss. It is also known that each form of energy is expressible as the product of two factors, one of which has been termed the 'intensity factor,' and the other the 'capacity factor.' Professor Ostwald, in the last edition of his 'Allgemeine Chemie,' classifies some of these forms of energy as follows:

Kinetic	energy is the product of	Mass into the square of velocity.
Linear	,, ,,	Length into force.
Surface	,, ,,	Surface into surface tension.
Volume	,, ,,	Volume into pressure.
Heat	,, ,,	Heat-capacity (entropy) into temperature.
Electrical	,, ,,	Electric quantity into potential.
Chemical	,, ,,	'Atomic weight' into affinity.

In each statement of factors, the 'capacity factor' is placed first, and the 'intensity-factor' second.

In considering the 'capacity factors,' it is noticeable that they may be divided into two classes. The two first kinds of energy, kinetic and linear, are *independent of the nature of the material* which is subject to the energy. A mass of lead offers as much resistance to a given force, or, in other words, possesses as great inertia as an equal mass of hydrogen. A mass of iridium, the densest solid, counterbalances an equal mass of lithium, the lightest known solid. On the other hand, surface energy deals with molecules, and not with masses. So does volume energy. The volume energy of two grammes of hydrogen, contained in a vessel of one litre capacity, is equal to that of thirty-two grammes of oxygen at the same temperature, and contained in a vessel of equal size. Equal masses of tin and lead have not equal capacity for heat; but 119 grammes of tin has the same capacity as 207 grammes of lead, that is, equal atomic masses have the same heat capacity. The quantity of electricity conveyed through an electrolyte under equal difference of potential is proportional, not to the mass of the dissolved body, but to its equivalent, that is, to some simple fraction of its atomic weight. And the capacity factor of chemical energy is the atomic weight of the substance subjected to the energy. We see, therefore, that while mass or inertia are important adjuncts of kinetic and linear energies, all other kinds of energy are connected with atomic weights, either directly or indirectly.

Such considerations draw attention to the fact that quantity of matter (assuming that there exists such a carrier of properties as we term 'matter') need not necessarily be measured by its inertia, or by gravitational attraction. In fact, the word 'mass' has two totally distinct significations. Because we adopt the convention to measure quantity of matter by its mass, the word 'mass' has come to denote 'quantity of matter.' But it is open to anyone to measure a quantity of matter by any other of its energy factors. I may, if I choose, state that those quantities of matter which possess equal capacities for heat are equal; or that 'equal numbers of atoms' represent equal quantities of matter. Indeed, we regard the value of material as due rather to what it can do, than to its mass; and we buy food, in the main, on an atomic, or perhaps, a molecular basis, according to its content of albumen. And most articles depend for their value on the amount of food required by the producer or the manufacturer.

The various forms of energy may therefore be classified as those which can be referred to an 'atomic' factor, and those which possess a 'mass' factor. The former are in the majority. And the periodic law is the bridge between them; as yet, an imperfect connection. For the atomic factors, arranged in the order of their masses, display only a partial regularity. It is undoubtedly one of the main

problems of physics and chemistry to solve this mystery. What the solution will be is beyond my power of prophecy; whether it is to be found in the influence of some circumstance on the atomic weights, hitherto regarded as among the most certain 'constants of Nature'; or whether it will turn out that mass and gravitational attraction are influenced by temperature, or by electrical charge, I cannot tell. But that some means will ultimately be found of reconciling these apparent discrepancies, I firmly believe. Such a reconciliation is necessary, whatever view be taken of the nature of the universe and of its mode of action; whatever units we may choose to regard as fundamental among those which lie at our disposal.

In this address I have endeavoured to fulfil my promise to combine a little history, a little actuality, and a little prophecy. The history belongs to the Old World; I have endeavoured to share passing events with the New; and I will ask you to join with me in the hope that much of the prophecy may meet with its fulfilment on this side of the Ocean.

The following Paper and Reports were read:—

1. *Reform in the Teaching of Chemistry.* *By* Professor W. W. Andrews, *Mount Allison University, Sackville, N.B.*

The reform here proposed may be set forth under the following heads:—

1. A more complete reorganisation of our subject-matter, a different order, a more constant correlation of the results obtained by different methods, and a larger use of the ideas of physics.

2. Methods of research by means of simple apparatus, thereby economising money, material, and time, and making laboratory hours more fruitful in results.

3. A method of writing equations denoting changes in energy and state of aggregation.

I. It goes without saying that any modern teaching makes large use of the Periodic Law as the basis of classification. In many excellent text-books this has been done to a certain extent. We should proceed farther in the same direction. Mastery of a greater number of facts is possible, and the educational and culture value of the study is increased.

It is well to introduce the law as soon as the idea of a difference between the reacting masses of the elements is made clear and some knowledge of acid and alkaline properties has been attained, and to do so by arranging the elements in linear order. Periodicity at once becomes evident, and a completion of the curves shows that all belong to one system. Mendeléeff's second table comes by sectioning this line. At first the periodicity should be shown in the case of one property of the elements only, and gradually the periodic system built up. Table I., which was exhibited to the Section, showed the periodicity of basic and acid properties in a diagrammatic form.

As in botany a plant, so in chemistry every element is to be studied as a representative of its family. Eight elements so discussed and experimented with are enough for an elementary course. The student should always be asked to reach some results of his own to earn the right to use the work of others.

Should we not begin with the well-known heavy metals, with their sensible properties and very marked reactions, instead of the intangible, odourless, and tasteless gases O, H, N, and so forth? It is easier to pass from them to the idea of atomic mass. Gram atoms of the different metals can be kept for illustration and experiment. To this order the cleanliness and simplicity of the plaster-of-Paris method lend themselves admirably. Besides, this is the true historical method.

Later on in the work the gases and the laws of gases and solutions may be profitably taken up. Indeed, study of the gases arises naturally from the experiments in

volatilisation before the blow-pipe, for the effect of environing vapors on the changes soon attract attention.

Chemistry is rapidly becoming a branch of physics. Physical methods and values may well be used, with this difference, that while in physics we deal with sensible volumes and molar masses, in chemistry we deal with atomic masses and volumes. It is very easy to pass from one to the other, as in atomic volume, atomic heat, and similar values.

When some atomic volumes have been computed and graphically illustrated as in Table II., which was exhibited at the meeting, at once the students will be ready to make certain deductions which future experiment will put to the test. Those elements which exhibit large atomic volumes may be expected to be comparatively soft, light, fusible, volatile, soluble, poor conductors of heat and electricity, chemically intense, exhibiting a constant valency, and are found to readily decompose water, liberating either O or H. Their compounds will be hard to reduce, show great heats of formation, are white or light-coloured, easily soluble, and of few types, *e.g.*, Na, K, Cl, Br, O, S, Ca, Sr, Ba. The elements which exhibit small atomic volume will be the opposites in every particular; for example, Cu, Ag, Pb, Mn, Cr, Fe, Ni, Co, &c. Table II. shows the effect of greater or smaller attraction between like atoms. So much of chemical knowledge may be based on the physical computations of specific gravity, united with the chemical idea of reacting masses. The periodic variation of atomic volume should then be exhibited, and the resulting chemical properties tested in the laboratory work. To prove or disprove a theory or a law is as valuable an exercise in research methods as the discovery of new truth. It has the advantage of giving some direction to the student's search.

We have in these physical values an explanation for the division of each family into two groups, which, along with family likenesses, exhibit marked differences, as Cu, Ag, and Au in Family I., and Zn, Cd, and Hg in Family II. The chemical relations of the members of any family to each other may be illustrated by two lines, coalescent at the top, but separating as we descend to the elements of greater atomic mass.

Dulong and Petit's law may be used for the computation of some atomic masses, for if we have a few blocks of different metals, of masses in grams proportional to their reacting masses, it can easily be found by experiment with small calorimeters that they all have the same capacity for heat, and the value 6·4 has a definite meaning, as the number of small calors or therms required to heat such masses 1 degree. The idea of atomic heat becomes easily so clear and definite that it may be tested in the laboratory and used in atomic mass determinations.

The most striking physical property used in chemistry is that of colour. The hint of any colour law at once awakens the spirit of research. It is easy so to grade experiments that the class readily make their own deductions. Carnelley's law may be stated in this form. Given the following chromatic scale,

White, colourless, violet;
Indigo, blue, green;
Yellow, orange, red;
Brown and black: then

$$\text{Depth of shade} \propto \frac{\text{Atomic Mass, Temperature, and Valency}}{\text{Atomic Volume, and Hydration}}.$$

The reactions on gypsum tablets give many examples of this.

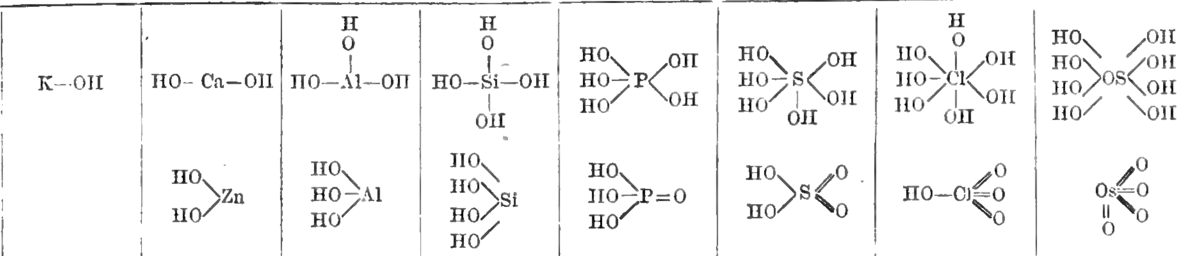
The general condition is that condensation of matter tends to move the shades toward the less refrangible end of the spectrum from white to black. Hydration generally has the effect of dilution, and rise of temperature the same effect as concentration, as Ostwald has shown to be the case in aqueous solutions, and as is found to be the case in solutions in borax and metaphosphoric acid.

The question of valency is one troublesome to the student, chiefly on account of the variation among the elements and variations in the behaviour of the one element. This may be reduced to order, and variations in valency are seen to be

TABLE III.—*Valency and Structure.*

M = Member of Family n = Number of Family	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	
				BINARY COMPOUNDS					
General Formula : Mx_n M_2O_n	MCl M_2O	MCl_2 M_2O_2	MCl_3 M_2O_3	MCl_4 M_2O_4	MCl_5 M_2O_5	MCl_6 M_2O_6	MCl_7 M_2O_7	M_2O_8	Chlorides Oxides
				SCHEME FOR TERNARY COMPOUNDS					
Dehydration ↓	MOH KOH	$M(OH)_2$	$M(OH)_3$	$M(OH)_4$	$M(OH)_5$ $-H_2O$	$M(OH)_6$ $-2H_2O$	$M(OH)_7$ $-3H_2O$	$M(OH)_8$ $-4H_2O$	Hydroxides and Hydroxy-acids
		H_2ZnO_2	H_3BO_3	H_4SiO_4	H_3PO_4	H_2SO_4	$HClO_4$	OsO_4	Ortho—ic Acids " ate Salts
			$(H_2B_4O_7)$	$H_6Si_2O_7$	$H_4P_2O_7$	$H_2S_2O_7$			Pyro—ic Acids " ate "
			HBO_2	H_2SiO	HPO_3				Meta—ic " " ate "
M_2O_n	K_2O	ZnO	B_2O_3	SiO_2	P_2O_5	SO_3	Mn_2O_7	RuO_4	Anhydrides (—ic)
Deoxidation ↓		H_2ZnO_2	H_3AlO_3	H_4SiO_4	H_3PO_4 H_3PO_3 H_3PO_2	H_2SO_4 H_2SO_3 H_2SO_2	$HClO_4$ $HClO_3$ $HClO_2$ $HClO$	RuO_4	Ortho—ic Acids " ous " Hypo— " " (except in Fam. VII.)
				H_4C	H_3P	H_2S	HCl		Hydrides

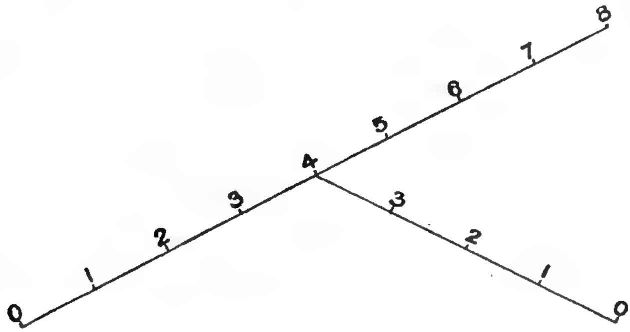
Structure of Molecules of Hydroxides



Ideal Forms

Ortho-acids

part of a system. The rise and fall of valency in the linearly arranged elements follows this form:—



In general terms, therefore, the valency for the eight families is the same as the number of the family. General formulæ can be written for the chlorides, oxides, and hydroxides, MCl_n, M_2O_n, $M(OH)_n$, where M stands for any member of a family, and n for the number of the family. The derivation of the ortho acids and salts, the pyro and meta salts and acids, is shown in Table III., which exhibits the ideal system of compounds which the elements tend to form. The gist of this is not new; but is not the whole system, exhibited *en bloc*, more easily comprehended than as usually presented, and would not a chart of this form in the lecture-room and laboratory simplify the matter of naming compounds and reduce a chaos of symbols and names into impressive order?

Isomorphism is another physical phenomenon easily shown and appreciated. It is of value because it gives an optical demonstration of the fact that when elements act with similar valency, they show other chemical likenesses, even when they are widely separated in the natural classification, *e.g.*, Ca, Sr, and Ba and dyad manganese; aluminium, and triad chromium, &c. The table of isomorphism becomes much more suggestive if, instead of being arranged in the form in which it is copied from text-book to text-book, it is set in the following form:—

TABLE IV.

I. Li, Na, Rb, Cs; Tl^{i}, Ag; Cu^{i}, Ag; Au^{i}.

II. Ca, Sr, Ba, Pb^{ii}; Mg, Zn, Mn^{ii}, Fe^{ii}; Ni^{ii}, Co^{ii}, Cu^{ii}; Cd, Be, In with Zn.
Ce^{ii}, La^{ii}, Di^{ii}, Er^{ii}, Y with Ca; Cu^{ii}, Hg^{ii} with Pb; Tl with Pb.

III. Al, Fe^{iii}, Cr^{iii}, Mn^{iii}; Ce^{iii}, U^{iii}, Ga; B, N^{iii}, Ta; N^{iii}, P^{iii} (in organic bases?)

IV. C, Si, Ti, Zr, Th, Sn; Fe^{iiii}, Ti.

V. As, Sb, Bi; P and V (in salts); N and P (in organic bases).

VI. S, Se, Te (in tellurides); Cr, Mn^{vi}, Te; Cr, Mo, W; As and Sb in the glances.

VII. Cl, Br, I; Mn^{vii}.

VIII. Os, Ir, Pt, Ru, Rh, Pd; Fe, Ni, Au; Sn, Te. See Ostwald's Outlines.

A table of solubility may be constructed of such symmetry that it is but a slight act of memory to carry all the more important cases used in analysis (see Table V.). After half an hour's practice with this table the student can pick out the soluble and insoluble salts from a page of formulæ.

TABLE V.—*Solubility of Compounds.*

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
All Salts *Soluble* of elements of great At. Volume, except Li_3PO_4 and Li_2CO_3. Phosphates and carbonates increase, and platinochlorides, tartrates, and alums decrease in solubility as we descend. *Insoluble.* Salts of Cu, Ag, Au as monads. Oxides. Sulphides. Halides.	Some Salts *Soluble.* Hydroxides and sulphides. Be, Mg, Ca, Sr, Ba $\downarrow$ more soluble Sulphates. Be, Mg, Ca, Sr, Ba $\uparrow$ more soluble Carbonates and Phosphates *insoluble.*	Most Salts *Insoluble.* Borates. Aluminates. Except of Fam. I.A. Borides.	Salts *Insoluble.* Carbonates. Silicates. Titanates. Zirconates. Except of Fam. I.A. Carbides. Silicides.	Most Salts *Insoluble.* Phosphates. Arsenates. Antimonates. Except of Fam. I.A. *Soluble.* All common nitrates. Tri-Meta phosphates.	Some Salts *Soluble* Sulphates. Selenates. Tellurates. Except Pb, Ba, Sr, Ca. *Insoluble.* Oxides. Sulphides & Sulphites. Selenides. Tellurides. Except of Fam. I.A.*	All Salts *Soluble.* All Chlorates. Bromates. Iodates. All Chlorides. Bromides. Iodides. Except Cu^{i}, Ag, Hg, Pb, Au^{i}, BiO, SbO, and Tl^{i}.	

* Especially insoluble are oxides, sulphides of small At. Vol. elements in all the families. Acid sulphides form some salts of Fam. I., and therefore dissolve in sulphides of the alkalies.

General Conditions of Solubility.

1. Substances dissolve each other better the more closely they resemble each other in structure.

*** Elements dissolve elements, *e.g.*, Pd in H; Fe, Mn, Ni, and Al in C; U, Cr, Ni, V, and W in Fe; O in Ag, &c.

Organic substances, like paraffins, containing only C and H, and bodies like sulphides, free from O, are insoluble in H_2O.

The richer they are in O the more soluble they are in water, *e.g.*, the sulphates.

Simple bodies dissolve in water, complex bodies in the complex alcohol, benzene, and ether (Belonbex).

2. In most cases where there is an imitative valency there is like solubility, as AgCl, HgCl, TlCl, CuCl, and AuCl.

3. The presence of a common ion reduces solubility.

4. Solubility generally increases with temperature, and decreases with atomic volume.

By making use of the kinetic theory of solutions under the head of equilibrium when the study of gases is entered upon, evaporation, diffusion, vapour and osmotic pressure, solution pressure, dissociation, tension, and ionisation may be treated together most advantageously. Clearer ideas are obtained, time is greatly economised, and living interest is added to the subject. Where chemistry is taken up subsequently to a course in experimental physics, or concurrently, the two courses may be made to supplement each other. In the descriptions of a family and the tabulation of values, the same principle of classification may be extended, and graphical curves will prove abundantly useful. Dr. M. M. Pattison Muir's articles in 'Watts's Dictionary' on the groups of elements are fine examples of what I mean, and my plea is for a larger use of this method in elementary classes.

II. *Simpler Apparatus for more fruitful Research Methods.*—The substitution of plaster tablets for charcoal, as a blowpipe support, has made possible for elementary and high schools a clean and cheap method for studying a wide range of chemical changes, without gas pipes and Bunsen burners, water pipes and pneumatic troughs, rubber and glass tubing, stills, retorts or sinks, gas generators, or hoods. These need be at the hand of the teacher only. On an ordinary school desk, with a two-cent blowpipe lamp as shown upon the table, a blowpipe, some paraffin wax for fuel, three or four ounce and one half-ounce bottles for reagents, and a supply of tablets, all of which can be kept in a box the size of an ordinary crayon box, experiments can be made testing the fusibility, volatility, oxidisability, and reducibility of the metals. The oxides, sulphides, chlorides, bromides, and iodides may be formed, and their colours and volatility and solubility noted.

The effect of coloured ions in solutions at high temperatures can be observed in borax and meta-phosphoric glasses without any expenditure for platinum wire. The quantity of chemical material needed is comparatively a negligible quantity. Within three minutes after a class has entered the laboratory, they have reached results and are recording their observations. In no other form of laboratory work do the compelled acts of judgment follow each other so rapidly. Research methods may be rigorously followed.

The following problems may be illustrated and studied by means of simple manipulations of this meagre apparatus: The changes which take place in a burning match and the products of combustion; the effect of mass action on chemical affinity; the energy changes which take place in fusion and volatilisation, and the effect of cold surfaces on the precipitation of sublimates; and the conditions of equilibrium between layers of heated gases, besides the formation of a very large number of compounds and exhibition of their properties. All results reached by the dry way should be correlated with analogous results reached in the wet way and the corresponding equations written.

III. Energy values are becoming of greater importance in science, and especially in chemistry. Changes of state of aggregation should always be noted. Therefore I have used a horizontal arrow to indicate a fused or dissolved substance, an upward pointing arrow to denote a gas, and a downward pointing arrow to denote a precipitate or solid. A common equation becomes, therefore,

$$\underrightarrow{AgNO_3} + \underrightarrow{HCl} = AgCl\downarrow + \underrightarrow{HNO_3}.$$

For the volatilisation of lead we would have in its simplest form

$$\begin{aligned} Pb\downarrow + \text{heat} &= \underrightarrow{Pb} \\ &\qquad + \text{heat} = Pb\uparrow. \end{aligned}$$

Or, if we wish to make it still more definite, as we may to great advantage, use *h.l.*, *h.v.*, and *h.s.* to represent respectively the heats of liquefaction, vaporisation, and sublimation; $sp.h\downarrow$, $\underrightarrow{sp.h}$ and $sp.h\uparrow$ to represent the specific heats in the solid, liquid, and gaseous states, *h.diss* for heat of dissociation, and *h.f.* for heat of formation. Then the equation for the raising of lead from 18° C. to 2,000° C. will be

$$\begin{aligned} & Pb\uparrow \text{ at } 18^\circ \text{ C.} + sp.h\downarrow \times (\text{M.P.} - 18) \text{ therms} = Pb\downarrow \text{ at melting-point} \\ & \qquad\qquad + h.l = \underrightarrow{Pb} \text{ at M.P.} \\ & \qquad\qquad + \underrightarrow{sp.h} \times (\text{B.P.} - \text{M.P.}) = \underrightarrow{Pb} \text{ at boiling-point.} \\ & \underrightarrow{Pb} \text{ at B.P.} + h.v. = Pb\uparrow \text{ at B.P.} \\ & \qquad\qquad + sp.h\uparrow \times (2{,}000 - \text{B.P.}) = Pb\uparrow \text{ at } 2{,}000^\circ \text{ C.} \end{aligned}$$

All equations are better written for atomic quantities. The above equation does not note any heat of dissociation of the gas, nor the heat used up in expansion against atmospheric pressure. These also may be indicated.

Practice in writing such equations leads to more thorough appreciation of the conditions in which chemical changes take place. It is remarkable in how few cases a work like Watts's 'Dictionary of Chemistry' gives all the numerical values for the symbols used above. This method of writing equations is easily extended to compounds.

In the plaster-of-Paris method results are reached so rapidly, and the method of procedure in different cases is so similar, that a rapid form of note-taking is allowable and necessary. By paragraphing in the following manner the note-books are more easily examined by the teacher, and permit of readier comparison of metal with metal:—

$Pb\downarrow + \text{O.F.} = PbO\downarrow$ brownish red when hot, pale brownish yellow when cold, fused oxide melts into the tablet.

$+ \underrightarrow{K_2S} = PbS\downarrow$ brownish black,

$+ \underrightarrow{HCl} =$ insoluble,

$+ \underrightarrow{HNO_3} =$ soluble, or decomposed.

Selected equation. $PbO\downarrow + \underrightarrow{K_2S} = PbS\downarrow + \underrightarrow{K_2O}.$

The position of the K_2S indicates that the solution is applied to the coating of lead oxide, and the position of HCl that it is applied to the lead sulphide; so also the HNO_3.

Again
$Pb\downarrow + \underrightarrow{I} + \text{heat} = PbI_2\downarrow$ chrome yellow, much more volatile than the oxide or sulphide.
Assay is black.

$+ \underrightarrow{K_2S} = PbS$ brownish black with red edges (Iodosulphide?)
$+ \underrightarrow{HCl} =$ partly removed.
$+ \underrightarrow{H_2SO_4} =$ changed to yellow.
$+ \underrightarrow{KSCN} =$ a black ring.
$+ H_2O =$ coating removed.
$+ KCN =$,, ,,

Selected equation. $PbI_2\downarrow + \underrightarrow{K_2S} = PbS\downarrow + \underrightarrow{2KI}.$

Heat toning of equation *h.f.* of PbS + 2 (80130) – (38900 + 101200) = *h.f.* of PbS + 19260 calories.

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2. *Report on the Teaching of Science in Elementary Schools.*
See Reports, p. 287.

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3. *Report on Wave-length Tables of the Spectra of the Elements.*
See Reports, p. 75.

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4. *Interim Report on the Proximate Chemical Constituents of the various kinds of Coal.*

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5. *Report on the Action of Light upon Dyed Colours.*
See Reports, p. 286.

FRIDAY, AUGUST 20.

The following Papers were read:—

1. *Helium.* *By* Professor W. RAMSAY, *F.R.S.*

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2. *Contributions to the Chemistry of the Rare Earth Metals.* *By* Professor BOHUSLAV BRAUNER, *Prague.*

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3. *On the Chemistry and the Atomic Weight of Thorium.* *By* Professor BOHUSLAV BRAUNER, *Prague.*

The author finds that the reaction which forms the basis of the separation of thorium from other Rare Earth Metals, is due to the formation of a new complex salt containing for one molecule of thorium oxalate, two molecules of ammonium oxalate, and four or seven molecules of water. The salt is decomposed by water, but it can be kept in solution by the presence of one additional molecule of ammonium oxalate. He shows how this behaviour may be used for the preparation of pure thorium salts. The thorium oxalate prepared in this way was analysed by determining the ratio of thorium oxide to oxalic acid (by means of permanganate), and the number 232·5 (O = 16) was obtained. The author shows that Meve's number, Th = 234·5, is too high, the oxalate being easily decomposed (basic salt is formed) by the action of hot water.

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4. *The Atomic Weights of Nickel and Cobalt.*[1] By Professor THEODORE W. RICHARDS, A. S. CUSHMAN, *and* G. P. BAXTER.

Four samples of the pure bromide of each metal were made and analysed. Two of the nickel preparations were freed from cobalt by ordinary processes, and two were purified by Mond's process. Fractional crystallisation of the ammonia-bromide was adopted as a means of further purification, after all known impurities had been removed; and the fourth sample of nickel was also precipitated fractionally by electrolysis. Each specimen was precipitated as hydroxide from the ammonia-bromide by boiling its aqueous solution in a platinum dish, thus insuring the absence of alkalies and silica. The hydroxide was ignited, the oxide reduced, and the bromide formed by the action of bromine vapour at a red heat. Sample I. was the least carefully treated, Sample IV. the most.

In the case of the cobalt, similar precautions were taken. The first sample was purified by fractional precipitation as the double nitrite with potassium; the second sample by successive conversions into a cobaltamine compound; the third by a combination of both of these methods; and the fourth by the resublimation of the third specimen.

All the samples of both bromides were sublimed as anhydrous crystals in a stream of hydrobromic acid gas; the specific gravity of the nickel salt was found to be 4·64, and that of the cobalt salt 4·91. The bromides were ignited, bottled, and weighed by means of the Richards-Parker drying apparatus;[2] and having been dissolved in water, they were decomposed by argentic nitrate. In the later analyses, the weight of the silver taken, as well as of the argentic bromide obtained, was determined.

Atomic Weight of Nickel.

Sample	Preliminary	Sample	Series II	Sample	Series III
I.	58·646	III.	58·691	III.	58·700
I.	58·708	III.	58·686	III.	58·709
II.	58·716	III.	58·696	III.	58·688
II.	58·650	III.	58·670	III.	58·689
III.	58·651	IV.	58·693	IV.	58·698
III.	58·700	IV.	58·690	IV.	58·675
III.	58·693	IV.	58·706	IV.	58·676
—	58·680	—	58·690	—	58·689

[1] *Am. Acad. Proc.*, xxxiii. pp. 95–128.
[2] *Am. Acad. Proc.*, xxxii. p. 59.

Atomic Weight of Cobalt.

Sample	Preliminary	Sample	Series II	Sample	Series III
I.	58·951	I.	58·975	I.	59·002
I.	58·975	I.	58·998	I.	58·955
I.	59·025	I.	59·009	I.	58·977
—	—	I.	59·001	I.	59·992
—	—	I.	59·997	I.	59·969
—	—	II.	59·982	—	—
—	—	II.	58·997	II.	58·999
—	—	III.	58·988	III.	59·003
—	—	IV.	59·010	IV.	58·999
—	58·984	—	58·995	—	58·987

The preliminary series in each case is of little consequence. The second series in each case represents results obtained from the weighing of the argentic bromide, while the third represents those obtained from the weighing of the silver. It is evident that the four samples of each bromide gave results essentially consistent with one another, and hence that the atomic weights of cobalt and nickel cannot be far from 58·99 and 58·69 respectively, if oxygen is taken as 16·000.

5. *On the Occurrence of Hydrogen in Minerals. By* M. W. TRAVERS.

6. *The Spectrographic Analysis of Minerals and Metals. By* Professor W. N. HARTLEY, *F.R.S., and* HUGH RAMAGE.

The steps by which the authors were led to this method of analysis were described and illustrated by lantern slides. After discovering the presence of gallium in the crude iron smelted at Middlesbrough, and tracing it to the Cleveland ironstone, it became necessary to examine other iron ores for this rare element. A combination of chemical and spectrographic methods was first used on 100 grammes of sample. The results were satisfactory as far as the detection of gallium was concerned, but the process occupied too much time.

A simple method, in which 0·5 gramme of the ore was rolled in filter paper and heated in the oxyhydrogen flame, the spectrum of which was meanwhile photographed, was tested with very satisfactory results. Not only could gallium be detected, but many other elements also at the same time. A large number of minerals and meteoric bodies have been examined by the method, and tabulated statements of the results were exhibited on the screen. Attention was directed to the wide distribution of the elements sodium, potassium, calcium, copper, silver, iron, manganese, and lead, and to the facts that every specimen of magnetite, bauxite, and meteoric iron examined contained gallium, as also did many specimens of blende and ironstone, and that siderite and the tin ores examined all contained the metal iridium.

Photographs of oxyhydrogen flame spectra of some of the elements were exhibited, and their simple character contrasted with the complex spark spectra of the same elements. One plate contained the flame spectra of the alkali metals, a second plate contained those of copper, silver, and gold; another plate those of iron, cobalt, and nickel. Similarities in the spectra of similar elements were indicated in these.

SATURDAY, AUGUST 21.

The Section did not meet.

MONDAY, AUGUST 23.

The following Papers were read:—

1. *Demonstration of the Preparation and Properties of Fluorine.* *By* Professor E. Meslans.

M. Meslans, after some introductory remarks referring to the researches of M. Moissan on the preparation of free fluorine, gave a demonstration of the properties of fluorine, and showed experiments illustrating its action on various elements and compounds.

He carried out these experiments with the aid of a new apparatus, made entirely of copper, except, of course, the lower ends of the electrodes, which, as usual, consisted of platinum. After having remarked that M. Moissan was the first to show that copper vessels may be employed in the preparation of fluorine, M. Meslans went on to describe the apparatus which he had just used, and which was now being utilised with the object of producing comparatively large amounts of fluorine, and for experiments on the possible industrial application of the element, which it is hoped may now become of easy attainment.

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2. *The Properties of Liquid Fluorine.* *By* Professor H. Moissan *and* Professor J. Dewar, *F.R.S.*

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3. *Demonstration of the Spectra of Helium and Argon.* *By* Professor W. Ramsay, *F.R.S.*

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4. *The Permeability of Elements of Low Atomic Weight to the Röntgen Rays.*[1] *By* John Waddell, *B.A., D.Sc.*

The paper is partly a discussion of data obtained by Gladstone and Hibbert and by myself, and already published, and partly an account of a reinvestigation of the points at issue.

I have maintained that there is no great difference between the permeability of lithium and sodium, and that it is hardly correct to say that lithium has next to no absorbent action on the Röntgen rays.

Beryllium and magnesium and boron and aluminium have been also compared as to absorbent power and found to be nearly equal, so that among the elements of low atomic weight (all below aluminium) there is no sudden or rapid rise of absorbent action with atomic weight.

Experiments intended to elucidate the peculiar granular appearance of coarse powders are also described.

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5. *Continuation of Experiments on Chemical Constitution and the Absorption of X Rays.* *By* J. H. Gladstone, *D.Sc., F.R.S., and* W. Hibbert.

In the work recorded last year the authors sometimes introduced an aluminium scale into their photographs for the purpose of giving quantitative comparisons of the amount of absorption of X rays due to various substances. They have now endeavoured to estimate the absorption by means of a Lummer-Brodhun photometer. The aluminium scale, when thus examined, showed that the rays absorbed by different thicknesses varied nearly in a logarithmic ratio.

Determining the absorption of different negative radicles of lithium salts, when the comparison is so made that the amount of substance traversed by the rays is

[1] Published in the *Chemical News*, October 1, 1897.

in the proportion of the chemical equivalents, the following was found to be the order:

$$O, C_2O_4, PO_4, NO_3, SO_4, Cl, ClO_3, Br.$$

Experiments made to determine whether an element has the same absorption in the metallic and the combined condition showed that in the case of copper (and perhaps other instances) the metal absorbed more than its oxides.

The change of atomicity of a metal between one series of its salts and another does not seem to be followed by any clearly marked difference in absorption.

In the case of carbon, the authors have been told by Sir William Crookes that the absorption of colourless diamond and the black forms of carbon are alike. In their own experiments it would appear that the absorption of carbon, when combined with hydrogen in amyl hydride, turpentine, benzene, naphthalene, and anthracene, differs little from that of charcoal or graphite, notwithstanding the addition of varying proportions of hydrogen, and the different manner of carbon linking. But benzene appears to be about 15 per cent. less absorbent than the others.

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6. *On the Action exerted by certain Metals on a Photographic Plate.* *By* Dr. W. J. Russell, *F.R.S.*

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7. *Photographs of Explosive Flames.—By* Professor H. B. Dixon, *F.R.S.*

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8. *Distribution of Titanic Oxide upon the Surface of the Earth.*[1] *By* F. P. Dunnington, *F.C.S., University of Virginia.*

In the 'American Journal of Science' for December, 1891, the author published an article under the above title, which presented estimations of titanic oxide in the soil from many quarters of our globe. Since that date he had secured a number of samples from portions of the earth not then represented. These include specimens from Australia, New Zealand, Africa, South America, and (ten from) British America; also samples taken from a depth of nearly a mile beneath the earth's surface.

Determinations of each of these are now presented, showing a range of figures from ·13 to 3·0 per cent. of the soil.

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9. *Deliquescence and Efflorescence of certain Salts.* *By* F. P. Dunnington, *F.C.S., University of Virginia.*

The affinity for water which results in deliquescence is considered as accompanied by the evolution of heat. The deliquescence of a solid is accompanied with an alteration of temperature which is the algebraic sum of the heat evolved by the chemical union of the body with water and of the cold produced through the liquefaction of the solid.

A series of determinations were made of the water absorbed from a moist atmosphere by certain salts during a period of twelve weeks, from which are selected the figures for 1, 2, 4, 6, 8, 10, and 12 weeks.[2]

One part of each of the anhydrous salts ultimately absorbed of water as follows:—Lithium chloride, 15·5 parts; Calcium chloride, 7·4 parts; Calcium nitrate, 4·7 parts; Magnesium chloride, 9·3 parts; and Magnesium nitrate, 6·4 parts.

From which it is calculated that one molecule of each of these bodies respectively has combined with: 36·8; 45·8; 43·1; 49·2; and 52·7 molecules of water.

[1] Printed in full in the *Chemical News*, Nov. 5, 1897.

[2] See *American Chemical Journal*, March 1897, pp. 227–232.

It is proposed to seek to ascertain the limit of the absorption of water by a salt by observation of the rise of temperature upon mixing a solution of the salt with more water.

Estimations were also made of the amounts of water lost in the efflorescence of certain salts upon prolonged exposure to the atmosphere. Figures are given showing the losses which took place after seven weeks' exposure of sodium carbonate, sodium sulphate, sodium phosphate, borax, ferrous sulphate, zinc sulphate, and copper sulphate. The sodium sulphate shortly became anhydrous.

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10. *Some Notes on Concentrated Solutions of Lithium and other Salts.*[1] *By* JOHN WADDELL, *B.A., D.Sc., Ph.D.*

The paper is a description of some incorporation experiments, in which lithium choride, sulphate, and nitrate are compared with other chlorides, sulphates, and nitrates.

The work was undertaken because in some experiments, already described in the 'Chemical News,' it was found that lithium nitrate absorbed more water than the calculated amount as compared with calcium nitrate. The experiments described in these notes show that the phenomenon observed before was accidental, as some chlorides are more absorbent than lithium chloride, and sodium nitrate, at all events, is more absorbent than lithium nitrate.

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11. *On the Formation of Crystals. By* W. L. T. ADDISON.

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12. *Note on a Compound of Mercury and Ozone. By* E. C. C. BALY.

The curious action of ozone on mercury has long been noticed. In some experiments on ozone lately made by the author it was necessary to treat mercury with large quantities of ozone, and he found that the change in the state of the mercury is due to the formation of a paste. This paste consists of a mercurial solution of a solid substance, which may be separated from the paste by filtration through chamois leather. The solid is then obtained as a hard metallic substance, having every appearance of an amalgam. This amalgam is a very stable compound at ordinary temperatures, but, on heating, changes to the black oxide of mercury, which, on further heating, gives mercury and the yellow modification of HgO. The substance is not attacked to any extent by hot or cold HCl or H_2SO_4, but is converted into HgO by HNO_3.

The author is at present engaged in investigating this substance with the view of determining its composition.

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13. *The Reduction of Bromic Acid and the Law of Mass Action. By* JAMES WALLACE WALKER, *Ph.D., M.A., and* WINIFRED JUDSON.

Many chemical reactions take place so rapidly that an experimental determination of the rate at which change is taking place is as yet an impossibility; others are of such long duration that the difficulty of keeping the external conditions constant during their whole course renders their accurate investigation also impossible; but a large number have already been examined in which the time required for a measurable amount of change varies from seconds to weeks with the nature of the reaction, and from a study of these the law connecting the mass of the substance with the time required for its transformation has been deduced. It is called the *Law of Mass Action.*

To take the simplest case, when one molecule of one substance is being transformed into one molecule of another substance, as expressed in the chemical equation

[1] Published in the *Chemical News*, October 8, 1897.

$A = A'$, it is found that if the reaction proceeds entirely to an end, the velocity is directly proportional to c, the concentration of A. But since all reactions of this nature do not go on at the same rate when their concentrations are the same, another factor must be introduced which is distinctive for each reaction. The velocity is therefore $V = k.c$, where k is a constant for each separate reaction. It is called the *velocity constant.* The concentration of c of course diminishes as the reaction proceeds, and therefore the velocity V also diminishes; but if we start with a known concentration a, and determine the amount x, which has been changed after a definite interval of time t, the concentration will now be $a-x$, and the amount changed in the next very small interval of time dt is called dx, and is proportional to the concentration at that point, so that the velocity is $\frac{dx}{dt} = k(a-x)$; x of course varies between the values 0 and a, so that the above equation gives on integration $k = \frac{1}{t} \log \frac{a}{a-x}$.

This is the equation for a mono-molecular reaction, and it can be employed to discover whether a particular reaction is mono-molecular or not. For this purpose experiments are made with several different values of the initial concentration a, and from each of these a large number of observations of x and its corresponding time t are obtained. When these experimental values for a, x and t are substituted in the equation

$$k = \frac{1}{t} \log \frac{a}{a-x},$$

if the reaction be really mono-molecular they will all give the same value for k. If they do not it is not a mono-molecular reaction.

When the reaction is *bi-molecular*—for example,

$$A + B = A' + B'$$

it is found that the velocity is proportional to the product of the concentrations of A and B, *i.e.*,

$$V = kc_1c_2 \text{ or } \frac{dx}{dt} = k(a-x)(b-x);$$

and if it is *poly-molecular*, *e.g.*,

$$A + B + C + \ldots. = A' + B' + C' + \ldots.$$

the velocity is proportional to the product of the concentrations of A, B, C, &c., *i.e.*,

$$V = k\, c_1\, c_2\, c_3 \ldots \text{ or } \frac{dx}{dt} = k\,(a-x)\,(b-x)\,(c-x)\ldots$$

If, in this last case, A and B are the same, the expression for the velocity becomes

$$\frac{dx}{dt} = k\,(a-x)^2\,(c-x)\ldots$$

which shows that when *two*, or generally n, molecules of a substance take part in the reaction, the concentration of that substance must be raised to the n^{th} power in the expression for the velocity of the reaction, *e.g.*, in the reaction

$$mA + nB = pA' + qB'$$

$$V - k\,c_1^m\,c_2^n \text{ or } \frac{dx}{dt} = k\,(a-x)^m\,(a-x)^n,$$

on substituting the observed values of a, b, x, and t in the integrated form of this equation it can be found by trial and error what the correct values of m and n are which always give a constant value for k.

A mono-molecular reaction ought to give a constant with the equation of the first

order, a bi-molecular with the equation of the second order, &c. Sometimes the orders so found are in agreement with what we should expect from the chemical equations, and sometimes they are not so, showing that the chemical equations do not always represent fully the mechanism of a reaction. For example, we should expect to find that both the inversion of cane sugar, in which one molecule of sugar is changed into one of glucose and one of laevulose, and the change of ammonium cyanate into urea

$$NH_4CNO = CO\begin{matrix}\diagup NH_2 \\ \diagdown NH_2\end{matrix}$$ are reactions of the first order.

The determination of the reaction velocity shows in the manner above described that this is true of the former, but that the latter is a reaction of the second order. We must therefore assume that the two ions of ammonium cyanate NH_4 and CNO react as two molecules.

Our object in this investigation was to determine the nature of the reaction between bromic and hydrobromic acids. According to the chemical equation $5\,HBr + HBrO_3 = 3\,H_2O + 3\,Br_2$ since there are in all 6 molecules on the left side of the equation, we should expect that only the equation $\frac{dx}{dt} = k(a-x)^6$ would give a constant value for k. This expectation is, however, not borne out by the experimental results, they show that the reaction, whose velocity is being measured, is only one of the *second* order instead of the *sixth*. We must therefore assume that the first stage of the reduction is expressed by the chemical equation $HBr + HBrO_3 = HBrO + HBrO_2$, and that these acids when formed are instantly decomposed by the hydrobromic acid present, thus:

$$HBr + HBrO = H_2O + Br_2 \text{ and}$$
$$3\,HBr + HBrO_2 = 2\,H_2O + 2\,Br_2.$$

The reaction consists in the formation of bromine and water, and the experimental method employed consists in titrating the liberated bromine by a standard solution of sodium thiosulphate. In the first set of experiments the free bromic and hydrobromic acids were liberated from the solution of their salts by addition of a definite large excess of sulphuric acid, the conditions being so arranged that its concentration was the same in each experiment. The duration of an experiment was noted from the time of addition of the sulphuric acid which started the reaction. In the first series the solution was $\frac{1}{100}$th normal with respect to KBr, and $\frac{1}{500}$th normal with respect to $kBrO_3$ and the mean value of k obtained from the integrated form of $\frac{dx}{dt} = k\,(5a-5x)\,(a-x)$ was 0·00423. A second series of experiments, in which the concentration of $kBrO_3$ was the same, but that of KBr doubled, *i.e.*, $\frac{1}{50}$ normal, gave as the mean value of k 0·00451; and when the concentration of the $KBrO_3$ was also doubled the mean value of k was 0·00427. These results are obtained by employing an equation of the second degree, so that the reaction whose velocity is being measured must be looked upon as bi-molecular. It consists in the production of $HBrO$ and $HBrO_2$ according to the equation given above, viz., $HBr + HBrO_3 = HBrO + HBrO_2$.

This leads us to expect that the reaction which, in the presence of a large excess of sulphuric acid—or of hydrogen ions—is bi-molecular, in its absence is of a higher order, probably tetra-molecular. Because, in the light of the ionic theory, the equation must be written thus—$2\overset{+}{H} + \overset{-}{Br} + \overset{-}{BrO_3} = HBrO + HBrO_2$, bromous and hypobromous acids being, from analogy with the corresponding chlorine compounds, very weak acids—*i.e.* very slightly ionised. This expectation was fully verified by an examination of the reaction between hydrobromic and bromic acids in the absence of sulphuric acid.

We performed two series of experiments, in the first of which the bromic acid

was $\frac{1}{100}$th and the hydrobromic acid $\frac{1}{20}$th normal, in the second $\frac{1}{50}$th and $\frac{1}{30}$th normal respectively. When the equation of the second order, viz.—

$$\frac{dx}{dt}=k\ (a-x)^2$$

was employed for calculation with these experimental results, it gave no approach to a constant value for k; but when they were substituted in the integrated form of $\frac{dx}{dt}=k\ (a-x)^4$—the equation of the 4th order—the first series gave a mean value of $0{\cdot}00113\div10^4$, and the second series $0{\cdot}00119\div10^4$. The agreement is as close as could be expected from the experimental method.

These experiments confirm the conclusion that the reduction of bromic acid takes place in stages, the first of which consists in the formation of bromous and hypobromous acids. It further shows that these acids, which have never been isolated, are excessively unstable in presence of hydrobromic acid, and points to a method for their preparation which we intend to investigate.

TUESDAY, AUGUST 24.

The following Papers were read:—

1. *On the Composition of Canadian Virgin Soils.*[1] *By* FRANK T. SHUTT, *M.A., F.I.C., F.C.S., Chemist, Dominion Experimental Farms.*

The soil investigations carried on in the laboratories of the Dominion Experimental Farms at Ottawa have included the chemical and physical examination of certain typical virgin (uncropped and unmanured) soils. The samples were carefully collected in the various provinces of the Dominion, and may be regarded as types or representatives of areas of fair uniformity and considerable magnitude.

Data respecting all the soils analysed are not included in this Paper, and only the more important elements of fertility of these here presented have been discussed. The majority of the samples considered are surface soils, but in a large number of instances the results obtained upon their respective sub-soils have been inserted.

The exact value of an ordinary soil analysis in ascertaining the fertility or productiveness of a soil is considered, and while it is admitted that hot hydrochloric acid (sp. gr. 1·115) dissolves larger amounts of mineral plant food than are of immediate availability to crops, it is pointed out that a knowledge of the 'maximum' amounts shows decisively deficiencies, if any exist, and thus indicates lines for rational and economic treatment of the soil with fertilisers. Further, it is held that soils possessing large 'maximum' amounts will in all probability prove more fertile than those showing smaller percentages, the climatic influences in both cases being equally favourable.

The diagnosis of a soil as regards productiveness cannot be made from chemical analysis alone, even if such includes a determination of the so-called 'available' plant food. The physical condition of the soil, drainage, rainfall, mean temperature, sunshine, &c., are factors that must receive careful consideration.

Pot or plot experiments with various fertilisers are at present the only means of gaining reliable or accurate knowledge of a soil's needs, but the incentive given by Dr. Dyer in 1894, in publishing his results by the 1 per cent. citric acid solution, has resulted in many agricultural chemists on this continent directing their attention to this important subject, and the probabilities are that, ere long, laboratory methods will be agreed upon for determining available plant food in soils.

The standards of fertility, as suggested by Dr. Hilgard, of the California Experi-

[1] Published *in extenso* in the *Chemical News* 1897, Oct. 15, *et seq.*

ment Station, are stated, and deductions made from Canadian data given. The latter show that good agricultural soils possess usually between ·25 per cent. and ·5 per cent. of potash—less than ·15 indicating the need of potassic fertilisers: phosphoric acid is usually between ·15 per cent. and ·25 per cent., but the adequacy of the element depends largely on the amount of lime associated with it. In lime, less than 1 per cent. in clay soils indicates that their productiveness will be increased by an application of a calcareous fertiliser. Peaty soils have always responded well to a dressing of lime. Richness in nitrogen invariably indicates, in Canada, loams of excellent productiveness. The larger number of our good soils contain between ·125 per cent. and ·225 per cent. of nitrogen; many, however, reach ·5 per cent., and some exceed 1·0 per cent. From the standpoint of chemical composition the richest soils of the samples examined comprise those collected on the prairies of the North-West and those of alluvial origin.

British Columbia.

As far as our investigations have carried us, the soils of this province fall into three well-marked groups: (*a*) Deltaic, as at the mouth of the Fraser and Pitt Rivers, very rich in plant food; (*b*) Valley soils, of alluvial origin and of more than average fertility; and (*c*) Bench and plateau soils at varying altitudes, frequently light and sandy, ranging from very poor soils to those of medium fertility.

Table I. presents data from twenty-nine samples, collected in the districts of Vancouver Island, New Westminister, Yale and Cariboo. The amounts of plant food and the chief physical character of these soils receive consideration, and deductions are made therefrom as to their relative fertility.

North-West Territories and Manitoba.

The prairie soils of these regions present considerable uniformity in character. They are justly noted for their productiveness, for analysis has shown them to contain, as a rule, large percentages of the essential constituents of plant food. Especially are they rich in humus and nitrogen. The prevailing prairie soil is a black or greyish-black loam, in which nitrification proceeds rapidly when the soil is tilled.

Attention is drawn to the fact that alkali soils are almost invariably found to contain an abundant supply of plant food. Thorough drainage and irrigation would convert them into fertile soils. Such methods, unfortunately, are not always feasible.

Table II. gives analytical data of eight typical surface soils from these provinces, those of a sample from the prairie soil of the Red River Valley being discussed in detail. The results demonstrate clearly that it may be classed among the richest of known soils.

Ontario.

Data are presented in Table III., obtained from soils collected in this district of Muskoka only. These soils are characterised by a preponderance of sand, being such as would be classed as light loams. Clay loams, however, are occasionally met with. The chief deficiencies are in humus and nitrogen (frequently resulting from destructive forest fires), and in lime. Speaking of them as a class, the Muskoka soils are scarcely heavy enough for wheat. Good yields of oats, potatoes, and root and fodder crops generally, are, under a good system of culture, readily obtained in favourable seasons.

Quebec.

The analytical results of sand and clay loams obtained from widely different areas in this province are contained in Table IV. Much variation, as might be expected, in composition is to be observed; but, though some show inadequate

quantities of certain elements for best results, all the surface samples come well within the ascertained limits of fertility, and many of the soils are seen to compare most favourably with those of recognised productiveness.

The Maritime Provinces.

The analyses of several typical soils in the Maritime Provinces are given in Table V. Prominent among these is one from the Sackville Marsh, N.B., at the head of the Bay of Fundy. The tides of this bay are phenomenally high, carrying with them vast amounts of detritus. Large deposits of this so-called marsh mud consequently form, and this material is highly prized by most farmers as an improver, being applied at the rate of 100 to 200 loads per acre. Reclaimed marsh lands are found to be exceedingly fertile.

Particulars are presented of a typical soil from Prince Edward Island. It is seen to be inferior in several particulars to many of our Western soils, and it would seem, therefore, that this province, justly known as a fertile one, owes its reputation rather to good soil texture and favourable climatic conditions than to large percentages of food constituents.

Averages and Deductions.

Table VI. shows the averages of the results from the soils examined, taken province by province. The data, however, are only to be interpreted as representing the composition of soils of large areas in the respective provinces.

General conclusions are drawn which indicate that in all the provinces large tracts of untilled land exist that would rank with the fertile soils of other countries, and, further, it is shown that many Canadian soils are possessed of most abundant stores of plant food, stores so vast as to allow of their most favourable comparison with the richest soils of which we have any knowledge.

TABLE I.—*Analyses of Soils (Water-free), British Columbia.*

No.	Locality	Surface or Subsoil	Character of Soil	Potash	Phos. Acid	Nitrogen	Lime	Loss on Ignition
1	Victoria, Vancouver Island . . .	surface	Valley soil, black loam.	·23	·19	·594	1·29	15·69
2	" " .	depth 12 to 18in.	—	·23	·19	·506	1·12	13·61
3	" " .	" 18 to 24in.	—	·26	·12	·146	1·01	4·63
4	Alberni " .	surface	Dark red clay loam .	·32	·08	·127	1·14	10·79
5	" " .	"	" sandy loam .	·17	·34	·163	1.00	11·32
6	Cowichan " .	"	" sandy loam, bench soil	·39	·32	·102	1·37	7·10
7	Ladners. New Westmr.	"	Alluvial, grey blk. loam	·52	·28	·610	·50	17·25
8	Squamish " .	"	Valley soil . . .	·38	·20	·091	1·68	3·38
9	Pitt Meadows " .	"	Alluvial black loam .	·36	·52	1·050	·32	31·14
10	" " .	subsoil	Greyish yel. sandy loam	·45	·13	·895	·33	6·37
11	Agassiz " .	surface	First bench . . .	·32	·24	·159	·86	6·87
12	" " .	"	Second bench . .	·35	·14	·101	·78	4·34
13	" " .	"	Valley	·39	·18	·154	·96	6·92
14	" " .	"	"	·35	·26	·155	·97	7·12
15	Chilliwack " .	"	" soil, alluvial .	·63	·21	·166	·98	7·72
16	" " .	subsoil	—	·51	·23	·108	·90	5·90
17	Mission, Yale . .	surface	Light grey, clay loam .	·45	·28	·124	1·86	3·96
18	" " . .	subsoil	—	·62	·33	·076	1·90	3·35
19	Guisachan " . .	surface	L. grey, sandy loam .	·32	·30	·077	1·22	2·66
20	" " . .	"	D. grey " .	·53	·30	·236	1·70	6·18
21	" " . .	"	" " .	·65	·38	·255	1·76	6·59
22	" " . .	"	" " .	·55	·34	·259	1·25	7·13
23	" " . .	"	L. grey " .	·45	·27	·045	1·61	2·02
24	Quesnelle, Cariboo .	"	D. grey " .	·39	·22	·399	17·77	12·01
25	" " .	subsoil	—	·53	·19	·108	3·80	4·60
26	Cottonwood River .	surface	Yellowish sandy loam .	·32	·34	·234	1·14	8·28
27	" " .	subsoil	Very sandy . . .	·16	·29	·057	·99	3·03
28	Cottonwood House .	surface	D. grey, sandy loam .	·57	·24	·412	1·07	13·04
29	" " .	subsoil	Yellowish grey . .	·47	·10	·050	1·22	3·02

TABLE II.—*Analyses of Soils (Water-free), North-west Territories and Manitoba.*

No.	Locality	Surface or Subsoil	Character of Soil	Potash	Phos. acid	Nitrogen	Lime	Loss on Ignition
30	Yorkton, N.W.T.	surface	Black, sandy loam	·49	·21	·501	·06	14·01
31	" "	subsoil	—	·42	·09	·130	·75	8·18
32	Saltcoats "	surface	Black, sandy loam	·34	·21	·571	2·90	13·54
33	Moosomin "	"	Black loam	·36	·11	·479	·95	11·79
34	Calgary "	"	—	·44	·17	·447	·92	12·23
35	Tilley Tp. "	"	—	·27	·18	·398	·37	11·13
36	Vermilion Hills "	"	—	·17	·17	·354	·50	10·43
37	Red River Valley, Man.	"	—	1·03	·29	1·005	1·89	26·29

TABLE III.—*Analyses of Soils (Water-free), Ontario.*

No.	Locality	Surface or Subsoil	Character of Soil	Potash	Phos. acid	Nitrogen	Lime	Loss on Ignition
38	Sinclair Tp., Muskoka	surface	Sandy loam	·11	·27	·186	·12	8·74
39	Chaffey Tp., "	"	" "	·08	·12	·139	·40	6·79
40	" "	subsoil	Sand	·08	·18	·074	·20	3·53
41	Franklin Tp., "	surface	Light grey loam	·61	·18	·103	·76	6·31
42	" "	subsoil	—	·02	·08	trace	·66	3·70
43	Perry Tp., "	surface	Sandy loam	·04	·18	·296	·08	9·40
44	" "	subsoil	—	·06	·18	·119	·13	5·10
45	Brunel Tp., "	surface	Clay loam	·46	·17	·084	1·28	2·94
46	" "	subsoil	—	·29	·09	·064	1·07	2·39

TABLE IV.—*Analyses of Soils (Water-free), Quebec.*

No.	Locality	Surface or Subsoil	Character of Soil	Potash	Phos. Acid	Nitrogen	Lime	Loss on Ignition
47	Arthbaska	surface	Sandy loam	·16	·17	·296	·35	8·68
48	"	subsoil	—	·17	·18	·184	·29	5·46
49	St. Adelaide de Pabos, Gaspe	surface	Red sandy loam	·44	·07	·215	·16	7·85
50	Soulanges, Gaspe	"	Grey sandy loam	·39	·33	·198	·47	7·76
51	" "	subsoil	—	·47	·30	·049	·73	3·67
52	Lievre River "	surface	Clay loam	·11	·19	·179	1·23	5·77
53	" "	subsoil	—	·10	·19	·171	1·17	5·62
54	Joliette "	surface	Black clay loam	·40	·28	·218	·82	8·06
55	" "	subsoil	—	·44	·29	·030	1·05	2·09
56	Bonaventure "	surface	Reddish-yellow clay loam	1·17	·19	·249	·10	12·37

TABLE V.—*Analyses of Soils (Water-free), Maritime Provinces.*

No.	Locality	Surface or Subsoil	Character of Soil	Potash	Phos. Acid	Nitrogen	Lime	Loss on Ignition
57	Sackville Marsh, N.B.	surface	Clay loam	·16	·16	·131	·13	5·83
58	Restigouche "	"	Yellow sandy soil	1·02	·10	·113	·23	5·46
59	Cumberland, N.S.	"	Sandy loam	·16	·09	·090	·06	3·37
60	S.-W. Mabou, "	"	"	·37	·09	·212	·05	6·97
61	King's County, P.E.I.	"	"	·47	·09	·106	·08	5·10

TABLE VI.—*Analyses of Soils—Averages. Surface Soils (Water-free).*

Number of Samples	Province	Potash	Phosphoric acid	Nitrogen	Lime
21	British Columbia	·42	·27	·262	1·17
7	North-west Territory and Manitoba . .	·44	·19	·537	1·08
6	Ontario (Muskoka only)	·22	·15	·135	·44
6	Quebec	·44	·20	·226	·52
5	Maritime Provinces	·44	·11	·130	·11
45	Average	·39	·18	·258	·66

2. *Analyses of Some Precarboniferous Coals.*[1] *By* Professor W. Hodgson Ellis.

The occurrence of anthracite in cavities of the calciferous sand-rock of New York, near the base of the Lower Silurian, was recorded in 1842 by Vanuxem.[2] Sterry Hunt[3] subsequently described a similar substance filling veins and fissures in rocks of Silurian age in Quebec and on Lake Superior. Chapman[4] proposed the name anthraxolite for this substance, to distinguish it from the anthracite of the coal measures, from which it differs chiefly in its mode of occurrence. Under this name Hoffmann[5] has given proximate analyses of samples from the Cambrian strata of Labrador.

In the neighbourhood of Sudbury a very considerable deposit of this mineral has been recently discovered, and has been described by Coleman.[6]

Mr. William Lawson and the author have published[7] an analysis of this Sudbury anthraxolite, and also of another specimen from Kingston, Ontario. Since then the author has had the opportunity, through the kindness of Dr. George Dawson, of analysing three other specimens. One of these is from Cap Rouge, Quebec, and is alluded to in the Report of the Geological Survey for 1863. The other two were collected by Mr. A. P. Low—one at Lake Mistassini, Quebec, and the other from Lake Petitsikapau, Ungava, Labrador.

The results of analysis were as follows:—

—	Cap Rouge	Mistassini	Petitsikapau
Moisture	0·19	1·75	0·81
Ash	9·02	1·07	48·37
Carbon	82·90	92·71	49·39
Hydrogen	5·50	1·02	0·67
Oxygen and Nitrogen . . .	2·39	3·45	0·76
	100 00	100·00	100·00

Taking these with our previous results, it appears that the composition of these Precarboniferous coals varies as widely as that of the coals proper. In the annexed table these analyses are compared with those of the author's and Mr. Lawson of the Sudbury and Kingston minerals, and also with the analyses given in Dana's 'Mineralogy' of a mineral from Lake Onega, Russia, described by Inostranseff, and

[1] Published *in extenso* in the *Chemical News*, 1897, p. 76, 186.
[2] *Geology of New York*, iii. 33. [3] *Geology of Canada*, 1863, p. 524.
[4] *Minerals and Geology of Central Canada*, p. 143.
[5] *Geological Survey of Canada*, 1894, p. 66 R.
[6] *Bulletin No. 2, Ontario Bureau of Mines.*
[7] *Proceedings of the Canadian Institute*, February 1897.

one from the Saxon Erzgebirge given by Sauer. These seem to complete the transition from asphalt to graphite.

Composition of Precarboniferous Coals calculated on the Dry Substance free from Ash.

—	Carbon	Hydrogen	Oxygen and Nitrogen
Cap Rouge	91·30	6·20	2·50
Kingston	90·50	4·20	5·50
Mistassini	95·20	1·20	3·60
Sudbury	96·40	0·50	3·10
Petitsikapau	97·12	1·32	1·56
Lake Onega	99·20	0·40	0·40
Erzgebirge	99·80	0·20	0·00

3. *The Constitution of Aliphatic Ketones.* *By* Professor P. C. Freer.

4. *The Chemistry of Methylene.* *By* Professor J. U. Nef.

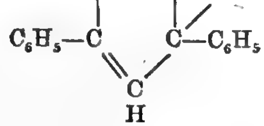
5. *Formation of a Benzene-Ring by Reduction of a* 1 : 6 *Diketon.* *By* A. Lehmann.

The 1 : 6 diketon was formed by condensation of benzil with two molecules of acetophenon, the former partially dissolved in the latter, and condensed with alcoholic solution of sodium hydrate (yield 80 per cent.).

$$\begin{array}{c} C_6H_5 \\ | \\ C:O \\ | \\ C:O \\ | \\ C_6H_5 \end{array} + \begin{array}{l} CH_3.CO.C_6H_5 \\ CH_3.CO.C_6H_5 \end{array} = 2H_2O + \begin{array}{l} C_6H_5 \\ | \\ C:CH.CO.C_6H_5 \\ | \\ C:CH.CO.C_6H_5 \\ | \\ C_6H_5 \end{array}$$

This by reduction with HI gave, together with other substances, a small yield (1 per cent.) of tetraphenyl-benzene. A ring formation therefore took place to some extent. Much better results were, however, obtained by reduction with zinc dust and acetic acid, and treating one of the products with phosphor-oxy-chloride.

The zinc-dust reduction gave a butylen derivative (diphenyl-dibenzoyl-butylen), a pinakon, a 'pinakolin,' and several other products. The butylen derivative gave with $POCl_3$ 40 per cent. of tetraphenyl-benzene. The latter reaction is a very interesting one—so far as I know without a direct parallel. The 'pinakolin,' strictly speaking, does not belong to this class. It is not a keton, but, most likely, a derivative of a compound standing in the same relation to benzene as ethylen to ethylen-oxide.



6. *Condensation Products of Aldehydes and Amides.* *By* CHARLES A. KOHN, *Ph.D., B.Sc.*

The products obtained originally by Roth by heating together benzaldehyde and acetamide or other aliphalic amides, or benzaldehyde and benzamide, are only formed in comparatively small quantity when the two substances are heated to incipient boiling, very many recrystallisations being necessary in order to get the resulting product pure, owing to the presence of by-products. After trying various condensing agents it was found that by passing dry hydrochloric acid gas into a boiling benzene solution of benzaldehyde and benzamide in the proportion of one molecule of the former to two of the latter, a yield of 75 per cent. of the pure product, which crystallises in long needles melting at 220°, is obtained. Analysis confirms Roth's formula, the condensation taking place according to the equation:

$$C_6H_5.CHO + 2C_6H_5.CO.NH_2 = \underset{\textit{Benzylidene dibenzamide.}}{C_6H_5.CH(NH.CO.C_6H_5)_2} + H_2O$$

The reaction, however, when carried out under similar conditions in the case of acetamide and benzaldehyde, yields the hydrochloride of acetyl-benzylidene-imide or acetyl-benzalimide as a beautifully crystalline compound, which is decomposed by all hydrolytic agents.

The reaction is best effected in a benzene solution containing equi-molecular proportions of acetamide and benzaldehyde into which the dry hydrochloric acid gas is passed. A yield of 70 per cent. of the hydrochloride is obtained, which begins to melt with decomposition at 130° to 131°. Both analysis and the quantitive decomposition of the substance by water point to the formula $C_9H_9NO.HCl$. Its formation is represented as follows:

$$\begin{aligned} &C_6H_5.CHO + CH_3.CONH_2 + HCl \\ &\qquad = C_6H_5.CH : N.CO.CH_3.HCl + H_2O. \end{aligned}$$

It is decomposed by water according to the equation:

$$\begin{aligned} &C_6H_5.CH : N.COCH_3.HCl + H_2O \\ &\qquad = C_6H_5CHO + CH_3.CONH_2 + HCl. \end{aligned}$$

This substance, therefore, appears to be the acetyl derivative of the benzalimide prepared by Busch, and presents similar conditions of instability to the latter. It is not attacked by cold water at once, but if gently warmed, and then allowed to cool immediately after solution has taken place, the analogous product to that obtained with benzaldehyde and benzamide results, a body previously prepared by Roth. It forms acicular needles, and melts at 233°. The change may be represented thus, one molecule of aldehyde being separated:

$$\begin{aligned} &{}^{+}\begin{matrix} C_6H_5.CH : N.CO.CH_3.HCl \\ C_6H_5.CH : N.CO.CH_3.HCl \end{matrix} + H_2O \\ &\qquad = C_6H_5.CHO + \underset{\textit{Benzylidene diacetamide.}}{C_6H_5.CH(NH.COCH_3)_2} + 2HCl. \end{aligned}$$

A good yield of this substance is obtained directly by passing dry hydrochloric acid gas into a melted mixture of the two constituents in suitable proportions.

Analogous decompositions by alcohols are under investigation; also the condensation products of other aldehydes, ketones and allied bodies both with amides, nitriles, thioamides and sulphamides.

By the action of sodium amide on benzaldehyde in benzene solution the sodium salt of benzalimide is obtained as a voluminous white gelatinous precipitate, which when dry forms an amorphous white powder, immediately decomposed by water with evolution of ammonia.

The equations representing these reactions are:

$$\begin{aligned} &C_6H_5.CHO + NaNH_2 = C_6H_5.CH : N.Na + H_2O \\ &C_6H_5.CH : N.Na + 2H_2O = C_6H_5.COH + NH_3 + NaOH. \end{aligned}$$

Ketones react similarly. The properties of these bodies and the reaction with ketonic and aldehydic bodies, as well as with simple ketones and aldehydes, are being studied.

A further object of the investigation is the preparation of the theoretically possible stereo-isomers of these imido-compounds. In addition, the therapeutic value of benzylidene-diacetamide and benzylidene-dibenzamide is being studied in conjunction with Dr. A. Grünbaum.

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7. *A New Form of Bunsen Burner.* *By* Hugh Marshall, *D.Sc.*

The ordinary form of Bunsen burner has several drawbacks. One of these, which makes itself especially felt in a large practical class, is the liability of the central gas jet to become choked by matters falling down the tube: fused beads of borax, &c., are particularly troublesome in this way. Various modifications were experimented with, in order, if possible, to obtain a form of burner which would overcome this difficulty. None of these were satisfactory until the expedient was adopted of abolishing the central jet altogether and introducing the gas through lateral openings. Burners on this principle were found to be superior to the old ones in several ways.

The base consists of a star-shaped gun-metal tripod, with an opening and short tube in the centre; at one side of the opening, below the tube, is a small rectangular block. This block carries the horizontal gas supply tube. A hole of suitable diameter is drilled through the block from the end of the gas tube to the central tube. This serves as a jet for the introduction of the gas. Into the central tube is screwed a vertical brass tube of convenient length, as in an ordinary burner.

The new style of burner therefore differs from the old in having an inclined lateral opening in place of a central gas jet; in having the bottom of the tube open right through to the bench, and in having no lateral air holes.

It is found that the flame can be turned down very low without requiring any regulation of the air supply, and, so far as that is concerned, an air regulator is almost superfluous. In order to obtain a luminous flame, however, a regulator is fitted on the under side of the base. It consists simply of a pivoted diaphragm of sheet brass, with an arm projecting beyond the base to admit of easy manipulation. Further improvements are contemplated with regard to this part of the mechanism, however.

A considerable number of burners have been made on this plan, and have been in use for several months. They work very satisfactorily.

WEDNESDAY, AUGUST 25.

The following Papers and Reports were read:—

1. *Molecular Movement in Metals.* *By* Professor W. C. Roberts-Austen, *C.B.*, *F.R.S.*

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2. *The causes of Loss incurred in roasting Gold Ores containing Tellurium.* *By* Dr. T. K. Rose.

It is a common experience that when ores containing tellurium are roasted considerable losses of gold occur. It has been generally believed that the losses are due to volatilisation, although little direct evidence of this has been brought forward.

In the paper experiments are described which point to a different conclusion. Samples of an alloy of gold and tellurium, containing 78·0 per cent. of the former,

were heated in a porcelain boat, inclosed in a porcelain tube, through which a glass tube was passed, kept cool by a current of cold water (hot and cold tube). The alloys were treated for different periods of time up to one hour, at temperatures between 500° and 1100° C., in currents of different gases, air, carbonic oxide, hydrogen, and water gas (carbonic oxide and hydrogen in about equal volumes) being used in successive experiments.

In each case the whole or a part of the tellurium was sublimed and condensed on the cold tube, but the sublimates in only one case contained a trace of gold, in the other cases the whole of the gold being found still to remain in the boat. The exception was when air was used as the atmosphere, the oxide of tellurium condensed on the cold tube in that case being found to contain 0·03 per cent. of the total gold originally present.

A second series of experiments on a tellurium ore from Western Australia containing over 1,000 oz. of gold per ton gave similar results.

The heavy losses incurred in roasting tellurides appear to be due in reality to liquation, the entectic of gold and tellurium having a very low melting point, so that some of it passes through the mass and soaks into the furnace bottom at temperatures below a red heat.

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3. *The Behaviour of Lead and of some Lead Compounds towards Sulphur Dioxide.* *By* H. C. JENKINS.

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4. *The Vapour Tensions of Liquid Mixtures.* *By* Dr. W. L. MILLER *and* T. R. ROSEBROUGH.

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5. *The Electrolytic Determination of Copper and Iron in Oysters.* *By* Dr. C. A. KOHN.

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6. *The Nitro-Alcohols.*[1] *By* LOUIS HENRY, *Professor of Chemistry in the University of Louvain.*

The method of preparation used by the author consists in the condensation of aldehydes with nitro-paraffins. The condensation takes place in the presence of water and of an alkali. A noticeable disengagement of heat accompanies the reaction. He found that the condensation of the nitro-paraffin with aldehyde is dependent upon the presence of hydrogen atoms linked to the carbon atom holding the nitro group, and it does not occur with the tertiary nitro-paraffins. The capacity of condensation also varies with the number of hydrogen atoms existing in the nitro-carbon chain. This capacity for condensation can be exercised either completely or incompletely and gradually, replacing but one of the two hydrogen atoms available at a time. The intensity of the reaction depends on the number of hydrogen atoms and on the molecular weight not only of the aldehydes but of the nitro-paraffins. It is greatest with formic aldehyde; it is at its maximum also in nitro-methane.

All nitro-alcohols are colourless, and cannot be distilled at ordinary pressure; most of them are liquid, those are solid which are derived from poly-acid alcohols.

The existence of the grouping $\begin{array}{c} CH_2NO_3 \\ | \\ CHOH \\ | \end{array}$ determines in these alcohols a special and intensely disagreeable odour; the haloid derivatives of the nitro-paraffins possess,

[1] See the Author's communications published in the *Bulletin de l'Académie royale de Belgique*, 1895, 1896, and 1897.

in a like manner, the power of combining with aldehydes except those containing the grouping $\overset{|}{\underset{|}{C}}\!\!<\!\begin{smallmatrix}X\\ NO_2\end{smallmatrix}$ free from hydrogen. The author has not been able to establish this condensation with acetone or with ethylene oxide such as $\begin{matrix}CH_2\\ |\\ CH_2\end{matrix}\!\!>$

It also appears not to take place with the aromatic aldehydes, notably with benzoic aldehyde. The basic hydrogen in the nitro-paraffins seems to behave in a manner similar to the hydrogen in hydrocyanic acid. He concludes also that these condensations are but particular cases of a general rule. All compounds containing the chain $-\overset{|}{\underset{|}{C}}-H$ with basic hydrogen, such as—

$$\begin{matrix}CO(OCH_3)\\ |\\ CH_2\\ |\\ CO(OCH_3)\end{matrix}\qquad\begin{matrix}CO(OCH_3)\\ |\\ CH_2\\ |\\ CN\end{matrix}\qquad\begin{matrix}CO(OCH_3)\\ |\\ CH_2\\ |\\ CO\\ |\\ CH_3\end{matrix}\qquad\begin{matrix}CH_3\\ |\\ CO\\ |\\ CH_2\\ |\\ CO\\ |\\ CH_3\end{matrix}\qquad\begin{matrix}HC\cdot(CO(OCH_3))_3\\ \\ \&c., \&c.\end{matrix}$$

are capable of condensation more or less easily with aldehydes, less with those where the aldehyde character exists with greatest intensity. The author submitted also a list of the nitro-alcohols which he has prepared up to the present time. The three possible nitro-propyl alcohols, together with a triclor-nitro-propyl alcohol were included, also five nitro-butyl alcohols and four nitro-hexyl alcohols. Of the halo-nitro-alcohols three were described, having formulæ—

$$\begin{matrix}CH_2OH\\ |\\ CBrNO_2\\ |\\ CH_2OH\end{matrix}\qquad\begin{matrix}CH_2OH\\ |\\ CClrO_2\\ |\\ CH_2OH\end{matrix}\qquad\text{and}\qquad\begin{matrix}CH_2OH\\ |\\ C\!<\!\begin{smallmatrix}Br\\ HO_2\end{smallmatrix}\\ |\\ CH_3\end{matrix}.$$

The author has been unable to obtain as yet a nitro-nitrile such as $CN\cdot CH_2NO_2$. A student in his laboratory however has prepared $CN\cdot CH_2\cdot CH_2\cdot CHrO_2$. The author is now engaged in studying the effect of the nitro group upon the intensity of the alcoholic character of these bodies, as well as the products of the oxidation of the nitrated primary and secondary alcohols, with the view of obtaining from them nitrated aldehydes and ketones, and the products of reduction of the nitro-alcohols leading to the preparation of corresponding alcoholic amines.

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7. *The Plaster of Paris Method in Blowpipe Analysis.*[1] *By* Professor W. W. Andrews.

In a paper published in the October number of the 'Journal of the American Chemical Society,' entitled 'Some Extensions of the Plaster of Paris Method in Blowpipe Analysis,' the author gave some account of the development of this method since Dr. Eugene Haanel first proposed this new support.[2] The new composition of the tablets, the new easily prepared and portable reagents, and the reactions they yield with the metals were there described. The author now gives some new applications of this support and some new reactions. The iodide coatings of the metals are shown.

The addition of boric acid to the calcium sulphate in the manufacture of the

[1] Published *in extenso* in the *Chemical News*, January 1898.

[2] This paper was republished in the *Chemical News*, November 1896.

tablets so fortifies them that they form a substitute, not only for charcoal, but also for platinum wire and bone ash. They resist the action of the fluxes, borax and metaphosphoric acid, and instead of beads in platinum loops we may with advantage produce coloured glassy films on the surface of the white tablets. Oxidation and reduction take place very readily in these films. All degrees of saturation may be observed at once. The colour changes due to change of temperature may be more accurately observed on account of the slower rate of cooling.

In assay work, if a fragment of a tablet be heated to redness for a few seconds and then pulverised, we have a material which may be moulded into a smooth cupel which does not blister, and which very readily absorbs the lead oxide in cupellation.

Potassium sulphocyanate, metallic iodine, potassium cyanide, potassium sulphide, and potassium cadmium cyanide are all easy to carry. With water they easily dissolve, and therefore solutions may be prepared anywhere. In the laboratory more rapid and better work can be done with the solutions. Potassium sulphocyanate is not always kept by the druggists, and its preparation by crystallisation in the laboratory is tedious. The simplest way to prepare the iodine solution is to mix fragments of potassium cyanide and sulphur, the latter a little in excess of the molecular proportions, in a test tube and fuse together, adding water while yet warm, and then adding metallic iodine to saturation. Dr Wirt Tassin, of Washington, uses a solid reagent made by fusing iodine and the sulphocyanate together with a little sulphur, and then powdering. This, if stable, ought to prove very satisfactory.

Here is a very effective portable blowpipe lamp which costs less than two cents. It consists of an ordinary druggist's tin salve box, with a piece of tin bent to form a wick-holder. The cover is bulged so as to shut down over the wick. The fuel is paraffin wax or stearin. The flame is smokeless, very hot, and with great reducing power and free from sulphur. Once filled, it burns for more than an hour. A test tube can be readily boiled over it. In private laboratories, and in schools in towns, where the electric light has supplanted gas, and afield, this little piece of simple apparatus has proved itself very useful.

Some reactions, not hitherto published, are those obtained by using the tablets as infusible filters. Films are obtained, for which I propose the name 'solution films,' to distinguish them from the sublimation films.

If to a solution of a lead salt a little potassium sulphocyanate be added, a precipitate of lead sulphocyanate tends to form. When, however, no precipitate is visible, if a drop be let fall on a tablet, instantly a bright-yellow spot is seen. The delicacy of many tests may be greatly increased by making use of this property of the tablets. It seems to be somewhat catalytic. Not only one, but as many as fifty or one hundred drops may fall upon the same spot, each drop deepening the coloration. Various confirmatory tests by wet or dry methods may then be made.

The iodine solution shows a remarkable power of dissolving gold. Gold leaf dropped on its surface almost instantly dissolves. If the solution containing gold be dropped on a tablet and the spot touched with the blowpipe flame, a fine pink film appears. It is better to add ammonium hydrate to the solution till decolorised. One drop of solution containing one part gold in thirty thousand will show a fine pink. Fifty drops will show gold present in one part in six hundred thousand and one hundred drops, one part in one million of solution. The test, therefore, may be made quantitative.

Platinum yields a slate-coloured film, chromium a film dark-green hot, and fine-green cold Copper yields a purple film, which, treated with sulphuric acid, disappears and darkens in oxidising flame. From some solutions the copper film is black. If a copper solution be dropped on a tablet and heated vapours of hydrobromic acid be blown over it, the purplish-brown of cupric bromide will appear. This will reveal copper, when present, one part in two million parts of solution.

Iron gives a brownish film, which sulphuric acid turns to Venetian red, and other acids remove. A little metaphosphoric acid added to the solution will prevent the formation of the film. Cobalt yields a pink film, which becomes, on hydration, a beautiful blue, and more strongly heated a black, which a drop of strong acid potassium sulphate removes.

Nickel yields a pale-green film, which, dehydrated, becomes a brownish-yellow and then a black. Ammonium hydrate turns the solution a fine blue.

Nickel may be detected in the presence of cobalt. The solution will probably be colourless, unless iron be present, when it will be amethystine. If a drop of the iodine solution be added to the section of the tablet, wetted by the metallic solution, and heated, the centre will be black, showing nickel, for in such circumstances the cobalt tends to leave a white centre, forming a black ring with sometimes a blue ring separating it from the centre, outside that a brownish yellow showing nickel, and farther out a spreading blue showing cobalt. The thiocyanate heated in the presence of an acid yields a yellow spot, which must be distinguished from the nickel film. The salts experimented with were the nitrates and sulphates, and when cobalt was six times as abundant as the nickel, the reactions of the latter were well marked.

Manganese, vanadium, molybdenum, ruthenium, and osmium also yield solution films.

Potassium cadmium cyanide has been found to be a reagent which affords a very delicate and ready test for sulphur even in the presence of selenium and tellurium.

Potassium sulphocyanate solution was added to a cadmium solution and dropped on a tablet and heated, and the scarlet of hot cadmium sulphide showed itself. Sixteen drops revealed the presence of cadmium in a $\frac{1}{400}$ normal solution, and this test was not interfered with by the presence of two hundred times as much zinc.

Zinc in the cobalt test responded with great delicacy, but aluminium gave no very delicate results, on account of the calcium reaction of the tablet itself.

Another extension of this method is to the compounds of organic chemistry.

Carbon gives a sooty coating which metaphosphoric and sulphuric acids increase. Tars and asphalts give a black tinged with green.

The phenols with the same reagents yield a black edged with a pinkish red. Picric acid is the only exception found so far. It gives a yellow. The following were among the phenols treated—carbolic acid, pyrogallol, salicylic acid, oils of coniine and wintergreen, Canada balsam, Burgundy pitch, resin, phenol phthalein, hydroquinone, and creolin. Many of the phenols when dropped on a tablet previously heated before the blowpipe show very brilliant and characteristic colours.

The paraffins yield no red, but heavy sooty, films. We have therefore group and individual tests.

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8. *Some Experiments with Chlorine.—By* R. Ransford.

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9. *Report on the Electrolytic Methods of Quantitative Analysis.*

See Reports, p. 295.

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10. *Report on Isomeric Naphthalene Derivatives.*—See Reports, p. 292.

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11. *Report on the Direct Formation of Haloids from Pure Materials.*

See Reports, p. 295.

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12. *Interim Report on the Bibliography of Spectroscopy.*

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13. *Report on the Carbohydrates of the Cereal Straws.*

See Reports, p. 294.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION—DR. G. M. DAWSON, C.M.G., F.R.S.

THURSDAY, AUGUST 19.

The President delivered the following Address:—

THE nature and relations of the more ancient rocks of North America are problems particularly Canadian, for these rocks in their typical and most easily read development either constitute or border upon the continental Protaxis of the North. The questions involved are, however, at the same time, perhaps more intimately connected with a certain class of world-wide geological phenomena than any of those relating to later formations, in which a greater degree of differentiation occurred as time advanced. A reasonably satisfactory classification of the crystalline rocks beneath those designated as Palæozoic was first worked out in the Canadian region by Logan and his colleagues, a classification of which the validity was soon after generally recognised. The greatest known connected area of such rocks is embraced within the borders of Canada, and, if I mistake not, the further understanding of the origin and character of these rocks is likely to depend very largely upon work now in progress, or remaining to be accomplished here.

This being the case, it seems very appropriate to direct such remarks as I may be privileged to make on the present occasion chiefly to these more ancient rocks, and the subject is one which cannot fail to present itself in concrete form to the visiting members of this Section. Personally I cannot claim to have engaged in extended or close investigations of these rocks, and there is little absolutely new in what I can say in respect to them; but work of the kind is still actively in progress by members of the staff of the Geological Survey, and the classification and discrimination of these older terranes present themselves to us daily as important subjects of consideration in connection with the mapping of vast areas; so that, if still admittedly imperfect in many respects, our knowledge of them must be appraised, and, at least provisionally, employed in a practical way in order to admit of the progress of the surveys in hand.

Although it is intended to speak chiefly of the distinctively pre-Cambrian rocks of Canada, and more particularly of the crystalline schists, it will be necessary also to allude to others, in regard to the systematic position of which differences of opinion exist. Of the Cambrian itself, as distinguished by organic remains, little need be said, but it is essential to keep in touch with the palæontologically established landmarks on this side, if for no other reason than to enable us to realise in some measure the vast lapse of time, constituting probably one of the most important breaks in geological history, by which the Cambrian and its allied rocks are separated from those of the Huronian and Laurentian systems.

In attempting to review so wide a subject and one upon which so much has already been written, the chief difficulty is to determine how much may be legitimately

eliminated while still retaining the important features. This must be largely a matter of individual judgment, and I can only hope to present what appear to me to be the essential points, with special reference to the geology of Canada. The useful object of any such review is, of course, to bring out what may now actually be regarded as established respecting these older rocks, and in what direction the most hopeful outlook exists for improving our knowledge of them. For this purpose, the best mode of approaching the subject, in the first place, and up to a certain point, is the historical one, and it will thus be desirable to recapitulate briefly the first steps made in the classification of the crystalline schists in Canada. This is the more appropriate, because of the substantial accuracy of these first observations, and the fact that they have since been largely buried out of sight by a copious controversial literature of later growth.

Soon after the Geological Survey of Canada was begun, now more than fifty years ago, Logan (who in the earlier years of the work may almost be said to have alone constituted the staff) found himself confronted with the great areas of crystalline rocks forming the continental Protaxis. The existing geological edifice has been so largely the result of the past half century of work, that it is not now easy to realise the elementary condition in which its foundations lay at that time. It was then but ten years since Sedgwick and Murchison had given form to their discoveries in regard to the Cambrian and Silurian, and a still shorter time since the definitive publication of the classification of the Cambrian and the appearance of the 'Silurian System,' while Hall, Emmons and others, working upon these lines, were actively engaged in building up a similar classification of the Palæozoic rocks of the Eastern States of the American Union. The Silurian and Cambrian had, in fact, but just been reclaimed from what Murchison speaks of as the 'vast unclassified heaps of greywacke' or 'transition limestones.'

It would have been quite appropriate at this date to relegate all underlying and more or less completely crystalline rocks to the 'Primary,' or 'Primitive,' or 'Azoic,' but such a solution fortunately did not recommend itself to Logan.

It was along the Ottawa Valley, in 1845, that the rocks subsequently classed under the Laurentian and Huronian systems were first examined in some detail. In that year Logan met with and accurately described, severally, rocks which we now refer to (1) The Fundamental Gneiss; (2) The Grenville Series; and (3) The Huronian. He speaks of the rocks of the first class as being in the main syenitic gneisses 'of a highly crystalline quality, belonging to the order which, in the nomenclature of Lyell, is called metamorphic instead of primary, as possessing an aspect inducing a theoretic belief that they may be ancient sedimentary formations in an altered condition.' In what we now call the Grenville Series, he describes the association of crystalline limestones and interbedded gneisses, adding that it appeared to be expedient to consider this mass as a separate metamorphic group, supposed to be newer than the last. Of the Huronian, the relations were at that time left undetermined, although it is observed that its beds hold pebbles of the underlying rocks, here the Fundamental Gneiss.

The following season was spent by Logan, and by his assistant Murray, on the north shore of Lake Superior, Thunder Bay and its vicinity being one of the regions especially examined. Without enumerating particular localities, it may be stated that Logan there grouped the rocks met with as follows, beginning with the lowest; the column added on the left giving the present nomenclature of the several series defined:—

Laurentian . . .	1. Granite and syenite. 2. Gneiss.
Huronian	3. Chloritic and partly talcose and conglomerate slates [schists.]
Animikie	4. Bluish slates or shales interstratified with trap.
Keweenawan . . .	5. Sandstones, limestones, indurated marls and conglomerates, interstratified with trap.

It is not distinctly stated that No. 3 rests unconformably on the older rocks, but the observation that granitic boulders were found in it, leads to the belief that such unconformity was assumed. Murray, however, supposed the junction as seen on the Kaministiquia to be conformable, and unites the first three subdivisions, as above given, in one series.

Logan further states, still referring to the same region, that the 'chloritic slates [schists] at the summit of the older rocks on which the volcanic formations rest unconformably, bear a strong resemblance to those met with on the upper part of Lake Temiscaming on the Ottawa, and it appears probable that they will be found to be identical.'

It will thus be observed that the progress in classification made, up to this date at least, entirely accords with the results of the latest investigations. The identity of the rocks placed third in the table with those of the Upper Ottawa was more than conjectured, and the existence of a great stratigraphical break at the base of what is now known as the Animikie was clearly recognised. The several formations were merely described. No specific names were given to them at this time by Logan, and it is further stated that the age of the highest formations (Animikie and Keweenawan) was in doubt, although some reason was found to support Houghton's[1] view (or what was believed to be his view), that these formations are lower than the Potsdam, or 'lowest fossiliferous formation.'

In 1847 and 1848, investigations were continued along the north shore of Lake Huron, of which the characteristic rocks are, it is stated, believed to form a single system. They are described as in part sedimentary (quartzites, conglomerates, &c.), and in part igneous (greenstones), the latter being both interposed between the sedimentary beds and intrusive. The 'slates' are particularly characterised by Murray as often chloritic, epidotic, and micaceous, and would now, of course, be more specifically termed schists.

Writing in 1849,[2] however, and later, in a communication presented to this Association in 1851, Logan, although still recognising the manifest unconformity at the base of the Animikie, speaks collectively of the 'Copper-bearing Rocks' of Lake Superior and Huron, including under this general term what are now known as the Huronian, Animikie, and Keweenawan series, and adds that it is 'highly probable' that all these are approximately equivalent to each other, and to the Cambrian of the British Islands.

In the Report for 1852–53 (published 1854), the name Laurentian was adopted for what had been previously designated merely as the 'metamorphic series,' and in the geological sketch printed in Paris in connection with the Exhibition of 1855 (which follows next in order of publication), this system is stated to consist almost exclusively of much altered and disturbed sedimentary beds. It is also, however, made to include some recognised intrusives, such as granite and syenites, forming parts of the mass, as well as the Labradorite rocks, which were afterwards for a time named Upper Laurentian, and to which further allusion will be made in the sequel. The name Laurentian is here therefore first employed exactly in the sense of the term 'Basement Complex,' introduced long afterwards, but under the distinct idea that most of the rocks are altered sediments, from which certain intrusive masses were not clearly separable.

In the same publication, the overlying series of Lakes Huron and Superior, including the Huronian proper, the Animikie and the Keweenawan, were collectively spoken of as the 'Huronian or Cambrian system.' These rocks are described as lying discordantly on the Laurentian, and as intervening between it and the lowest known fossiliferous strata. There being no other recognised place for such rocks in the scheme of the day, they are consequently supposed to represent the Lower Cambrian of Sedgwick.

It is unnecessary to follow in order the investigations carried on for a number of subsequent years, but reference may now be made to the 'Geology of Canada,' of 1863, in which all previous results of the Survey to that date were collected and

[1] Then State Geologist of Michigan.
[2] *Report on the North Shore of Lake Huron.*

systematised. In this volume, after stating that Hall's nomenclature of the Palæozoic rocks in the State of New York had been adopted unchanged for the adjacent Canadian territory, 'in the interests of unity of plan for future researches,' Logan writes:—'To the Azoic rocks no local names have yet been applied in any part of America except in Canada,' and adds:—'The names of the Laurentian and Huronian systems or series, which we have been accustomed to apply to them, are allowed to remain unchanged, particularly as they have been recognised abroad, and have been made by other geologists a standard of comparison both in America and Europe.'

In Chapter V. of this volume the 'Upper Copper-bearing Rocks of Lake Superior' are separately treated, and are recognised as comprising two groups which are stated to overlie the Huronian unconformably. These groups are those now known as the Animikie and Keweenawan.

There can be no doubt about the classification intended at this time, and the rocks are correctly laid down on the atlas prepared to accompany the volume, but in consequence of an unfortunate error in the geographical description of the distribution of the Huronian about Thunder Bay, that arose in 1846 and was repeated in 1863, several later investigators have been led to regard the rocks of the 'Upper Copper-bearing Series' as those of Logan's typical Huronian, and to suppose that when examining these rocks they were dealing with those intended to be classed as Huronian. Irving, Winchell, and others have adopted this mistaken view, which it is particularly necessary to refer to here, as it has been the chief cause of all subsequent misapprehension in regard to the 'Original Huronian.'[1]

The temporary grouping of the Huronian proper with the 'Upper Copper-bearing Series' (Animikie and Keweenawan), on the grounds already explained, as 'Huronian or Cambrian,' together with the employment (proper enough at the date) of the term 'slates' for rocks that would now be named schists, further assisted in giving colour to the erroneous view just referred to.

In a second geological sketch of Canada, printed in Paris at the time of the International Exhibition of 1867, the same classification is maintained, but to it is added the Upper Laurentian or Labradorian. This sketch was actually written by Hunt, but it was an official publication, correctly representing the views held

[1] As already stated, the relations of the principal rock-series of the vicinity of Thunder Bay had been correctly outlined in 1846, although the series had not at that time been named. The Kaministiquia River section had been examined by Murray, who also correctly described the distribution of the series there, stating that the 'granite, syenite, gneiss, micaceous and chloritic schist' (Laurentian and Huronian) find their southern limit on a line running from the falls on that river to the 'head of Thunder Bay,' while the 'Upper Slates (Animikie) rest upon them and occupy the country between such a line and Lake Superior' (*Report of Progress*, 1846–47, p. 51). In combining his own results with those of Murray, Logan describes the southern line of the granite, gneiss, and chloritic slates as 'commencing in the vicinity of Fort William,' or at the *mouth* of the Kaministiquia, although the falls, at which this line had been determined by Murray, are some twenty miles up the river. Proceeding (*op. cit.* p. 25) to describe the extent of the 'superior trappean formations' (Animikie and Keweenawan), he then reverts to the line previously stated, making these rocks to terminate locally where he had said the older rocks began. In recasting the earlier observations for the volume of 1863 (no further work having meanwhile been done at this place), Logan is thus naturally led to state that the Huronian (*i.e.* the 'Chloritic Slates') *occupies the coast east of the Kaministiquia*, whereas this coast, for ten or eleven miles, is actually occupied by Animikie rocks. Subsequent investigators, inspecting this coast-line with the volume of 1863 as a guide, very naturally thus assumed that they were examining Logan's 'typical Huronian,' or a part of it. It is in consequence only of a too consistent adhesion to this misunderstanding, that it has been found necessary to speak of an 'Upper Huronian,' and refer to an 'inter-Huronian' unconformity. The so-called Upper Huronian is no part of the system as understood by the Canadian Survey. One cannot fail to note, in reading much that has been written on this subject, that the importance of the great unconformity at the base of the Animikie was realised only after a new classification had been adopted, in which it had practically been ignored.

at that time, and may be accepted as Logan's last word on the subject. As thus defined and established, he left the Laurentian and Huronian systems.

In so far as the stratigraphical relations of the Laurentian, Huronian, and 'Upper Copper-bearing Series' are concerned (leaving out of consideration the Labradorian), it is thus manifest that the conclusions originally formed from actual study on the ground were those finally held by Logan. The reference for a time of the Huronian proper and the 'Upper Copper-bearing Series' together to the Lower Cambrian, meant only that, as then understood, there was no other systematic position recognised to which they could be assigned. That a great unconformity existed between these two systems was never doubted, but for some years Logan was not prepared to take the bold position of constituting a separate Huronian system beneath the lowest Cambrian; he was, on the contrary, anxious, if possible, to bring the Canadian section within the lines established in the classic region studied by Sedgwick and Murchison. The introduction of new systematic terms was at that time considered somewhat seriously. When eventually compelled to take this step (in 1857), he confined the name Huronian to rocks antedating the great break at the base of the 'Upper Copper-bearing Series' (Animikie), embracing those first seen by him on the Upper Ottawa and on Lake Huron, with their representatives elsewhere, under this new system.

In so far as nomenclature goes, Logan thus certainly modified his original application of the name Huronian; it was not, however, as has been contended, to create an 'extended Huronian,' but on the contrary to restrict the name to rocks beneath the great unconformity at the base of the Animikie. The change was necessitated by the progress of investigation and by the recognition of an upper division of the 'Azoic,' beneath anything that could legitimately be classed as Cambrian. It was made by the author himself, and involved no departure from the law of priority or from any other acknowledged rule. In finally eliminating these upper rocks from his Huronian system, he was no doubt influenced by Whitney's criticisms of 1857,[1] which were in part correct, although largely devoted to the very conservative contention that all stratified rocks below the great break were inseparable, and should be included in an 'Azoic System.' This influence may be traced in an important paper, of but three pages, communicated to the American Association for the Advancement of Science a few months later than the date of that above referred to, in which, while the name Huronian is reaffirmed for the rocks of Lake Huron and Lake Temiscaming, which are taken as typical of the system, nothing further is said of those now known as Animikie and Keweenawan.

In the summary volume of 1863, to which allusion has already been made, the existence of an Upper Laurentian, Labradorian or Norian Series was first tentatively indicated in a supplementary chapter. It is unnecessary to follow here the history of the rocks so classed, for the supposed series has not stood the test of later discussion and research, due chiefly to Selwyn and Adams. The apparently stratified rocks often included in it are now understood to be foliated eruptives. The recognition achieved by this and by other more or less hypothetical series about this time may be traced to the brilliant chemico-geological theories advanced by Hunt, previous to the general acceptance of modern petrographical methods.

In a similar manner, and very justly so, Logan, as a field geologist, was influenced by the views held by Lyell in the early editions of his 'Principles,' to accept without reservation the foliation of crystalline rocks as indicative of original bedding. This was, at the time of his early researches and thereafter for many years, the accepted view, although Dana, in a paper read before the American Association for the Advancement of Science in 1843, had already held that the schistose structure of gneiss and mica-slate was insufficient evidence of sedimentary origin; and Darwin, a few years later, had published his 'Geological Observations,' including a remarkable chapter on cleavage and foliation, in which he advocated a similar view. No such doctrine, however, achieved general recognition until long afterwards, while that class of facts remaining to be determined chiefly by the micro-

[1] *Am. Journ. Sci.*, vol. xxiii. May, 1857

scope, which may be included under the term 'dynamic metamorphism,' were wholly unknown and unforeseen.

In admitting that chemical, metamorphic, and uniformitarian hypotheses were thus given, in turn, undue weight, it is not to be assumed that the advances made under these hypotheses have been entirely lost; it has been necessary only to retreat in part in each instance, in order to fall again into the more direct road.

In late years, modern microscopical and chemical methods of research have been applied to the ancient crystalline schists of Canada—the older work has been brought under review, and new districts have been entered upon with improved weapons. Here, as in other parts of the world, investigations of the kind are still in active progress; finality has not been reached on many points, but the explanation of others has been found. One advance which deserves special mention is the recognition of the fact that a great part of the Huronian is essentially composed of contemporaneous volcanic material, effusive or fragmental. This was first clearly stated by Canadian geologists, but has only become generally admitted by degrees, in opposition to prevalent theories of metamorphism and cosmic chemistry.

The first opportunity of studying these Archæan rocks in detail, under the new conditions, fell to Dr. A. C. Lawson, then on the staff of the Canadian Survey, in the vicinity of the Lake of the Woods and elsewhere to the west of Lake Superior. In that part of the Protaxis, the Laurentian appears to be represented only by the Fundamental Gneiss, and the Huronian, by a series to which a local name (Keewatin) was appropriately given,[1] but which is now known to differ in no essential respect from many other developments of the same system. The Huronian stands generally in compressed folds, and along the line of junction the gneisses are related to it in the manner of an eruptive, penetrating its mass and containing detached fragments from it. The same or very similar relations have since been found to occur in many other places.

Arguing from observations of the kind last mentioned, it was too hastily assumed by some geologists that the Laurentian as a whole is essentially igneous, and later in date than the Huronian. The conditions are, however, not such as to admit of an unqualified belief of this kind, even in regard to the Fundamental Gneiss. We may go so far as to assume that these rocks (occupying as they do much the larger part of the entire Protaxis) constitute a great 'batholitic' mass of material at one time wholly fluent; but even on this hypothesis some primitive floor must have existed upon which the Huronian and the similarly circumstanced Grenville Series were laid down, and no such enormous substitution can have obtained as to result in the replacement of the whole of this floor by exotic material.[2] It seems much more probable that but limited tracts of the Fundamental Gneiss have passed into a fluent condition when at great depths in the earth's crust, and various arguments may be adduced in favour of a belief that the observed lines of contact might be those along which such fusion would be most likely to occur.[3] Moreover, the Huronian in many and widely separated localities is found to contain water-rounded fragments of syenitic, granitic and gneissic rocks, forming conglomerates, which may often be observed to pass into schists, but still plainly indicate that, in these places at least, materials not unlike those of the Fundamental Gneiss and its associates were at the surface and subject to denudation. Such materials cannot be regarded as parts of any primeval superficial crust of the earth in an original condition. They represent crystalline rocks formed at great depths, and under conditions similar, at least, to those under which the Fundamental Gneiss was produced. They imply a great pre-Huronian denudation, and show that the Huronian must have been deposited unconformably either upon the

[1] In the Archæan, local names are particularly useful, inasmuch as correlation must proceed on lithological and stratigraphical data, more or less uncertain when extended to wide areas, even in the case of the older and more homogeneous strata of the earth's crust.

[2] For analogous phenomena of much later date geologically, see *Annual Report Geological Survey of Canada*, 1886, p. 11 B.

[3] Hypotheses on this subject are well summarised by Van Hise. *Annual Report U.S. Geol. Survey*, 1894–95, p. 749.

Fundamental Gneiss itself, or upon rocks occupying its position and very similar to it in character. There can be no reasonable doubt that the mass of what now constitutes the Fundamental Gneiss originally existed as the floor upon which the Huronian was deposited.

The name Archæan has been adopted and employed by the Geological Survey of Canada in the sense in which it was introduced (in 1874), and consistently maintained by Dana—*i.e.* to include all rocks below the great hiatus of which evidence was first found in the Lake Superior region. The author of the name never assented to its restricted application as proposed by Irving and followed by Van Hise and others, and as a synonym for the Fundamental Gneiss or 'Basement Complex' it is not only unnecessary but is scarcely etymologically correct, if we admit that a part of the 'Complex' is of comparatively late date.

We have reached a point at which we may ask what is now our conception of these Archæan rocks in Canada, and more particularly in the great Protaxis, as resulting from the most recent investigations of a critical kind. The reply may be given briefly from the latest reports of those still at work on the problems involved as follows:—

The *Laurentian* comprises (1) the Fundamental Gneiss or Lower Laurentian (also referred to as the Ottawa Gneiss or Trembling Mountain Gneiss in older Reports), and (2) the Grenville Series. An important part of the gneisses of the Grenville Series has been shown by chemical analysis to be identical in composition with ordinary Palæozoic argillites, and they are interbedded with quartzites and massive limestones, also evidently of aqueous origin, and in some places abounding in graphite. These beds are, however, closely associated with other gneisses in which orthoclase largely preponderates that have the composition of igneous rocks. The Fundamental Gneiss consists chiefly, if not exclusively, of rocks of the last-named class, the banding or foliation of which, though now generally parallel to that of the Grenville Series, has probably been produced mainly or entirely by movements induced by pressure, in a mass originally differing more or less in composition in its different parts. The two series are sometimes separable on the ground locally, but with difficulty; in other places they cannot be clearly defined.[1]

The Upper Laurentian, Labradorian, Norian or Anorthosite group, maintained for a number of years on the evidence already mentioned, is found to consist essentially of intrusive rocks, often foliated by pressure, later in age than the Grenville Series, but in all probability pre-Palæozoic.

The *Huronian* comprises felspathic sandstone or greywacke more or less tufaceous in origin, quartzites and arkoses passing into quartzose conglomerates and breccia conglomerates, often with large fragments of many different varieties of granite, syenite, &c., diorite, diabase, limestones, and shales or slates changing to phyllites in contact with the numerous associated igneous masses. Over wide areas altered greenstones and their associated tuffs preponderate, often with micaceous, chloritic, sericitic and other schists, many of which are of pyroclastic origin, although some may represent ordinary aqueous deposits, and all have been much affected by subsequent dynamic metamorphism.

The Huronian rocks have not yet been found in distinct relation to those of the Grenville Series, but are generally in contact with the Fundamental Gneiss, in the manner previously alluded to. Where not composed of volcanic material it appears to be largely of a littoral character, while the Grenville Series seems rather to indicate oceanic conditions.

No reference has so far been made to the development of Archæan rocks, known as the 'Hastings Series.' The rocks thus named occupy considerable tracts to the south of the Ottawa River, west of the City of Ottawa. They were originally classed by Logan and Murray with the Grenville Series of the Laurentian, although Murray soon after insisted on their peculiar features, and they came to be recognised by the above geographical name during subsequent discussions as to their systematic position, by the authors above referred to, and by Hunt, Vennor, and Macfarlane. These rocks are particularly alluded to now, because later work seems to show that both the Grenville Series and the Huronian are represented in

[1] Cf. Adams, *Annual Report Geological Survey of Canada*, 1895.

the district—in so far, at least, as lithological characters may be depended on. They include a preponderance of thinly bedded limestones and dolomites, finer in grain and usually less altered than those of the typical Grenville Series, associated with conglomerates, breccias and slates still retaining complete evidence of their clastic origin.

It is in this Hastings region that careful investigation and mapping are now in progress by several members of the Canadian Survey, with the prospect of arriving at definite results respecting the relations of the Grenville Series and the Huronian. It is too early to forecast what these results may be, for the question is one which must be approached with an open mind; but the work already completed by Messrs. Adams, Barlow, and Ells, appears to sustain the suggestion that both series occur, and to indicate that they may there be so intimately connected as to render their separation difficult. It must be borne in mind that, although the relations of the Grenville Series and those of the recognised Huronian to the Fundamental Gneiss are very similar, they characterise distinct tracts, to which the Hastings district is to some extent geographically intermediate, although most closely connected in this respect with the Grenville region.

Reverting to the original classification of the Archæan of the Canadian Survey, as developed in the field by Logan and his assistants, we may now enquire—In how far does this agree with the results of later work above outlined? In the main, this classification still stands substantially unaltered, as the result of all honest work carefully and skilfully executed must. The nomenclature adopted is still applicable, although some of our conceptions in regard to the rocks included under it have necessarily undergone more or less change.

The Laurentian is still appropriately made to include both the Fundamental Gneiss and the Grenville Series; although at first both were supposed to represent 'metamorphic' rocks, it was even then admitted (1855) that these embraced some plutonic masses practically inseparable from them. Later investigations have increased the importance of such plutonic constituents, while at the same time demonstrating the originally supposed sedimentary origin of the characteristic elements of the Grenville Series; but the admission of so large a plutonic factor necessarily invalidates in great measure the estimates of thickness based upon the older reasoning, under which any parallelism of structure was accepted as evidence of original bedding.

Whatever views may be held as to the propriety of including rocks of the two classes under a single name, the necessity of so doing remains, because of the practical impossibility of separating them over any considerable area for the purpose of delineation on the map. No advance in knowledge is marked in substituting for Laurentian, with its original concept of a stratified time-series, such a name as 'Basement Complex.' It may, indeed, yet prove that the homogeneity of the Laurentian is greater than is at present supposed, for a mass of strata that included ordinary sediments, arkoses, and contemporaneous volcanic deposits of certain kinds, in which the arkose and volcanic constituents preponderated in the lower beds, might, under metamorphism at great depths, produce just such a combination as that of the Grenville Series and the Fundamental Gneiss, the latter representing an aggregate result of the alteration of that part composed chiefly of volcanic material or of arkose—in fact, under the conditions assumed, the lower mass could not now well exist under any other form than that actually found in the Fundamental Gneiss. In his address at the Nottingham Meeting of this Association, Teall has clearly pointed out that, in such cases, the chemical test must necessarily fail, and that the character and association of the rocks themselves must be given a greater weight.

The Huronian proper, under whatever local names it may be classed, still remains a readily separable series of rocks, with peculiar characters, and economically important because of the occurrence in it of valuable minerals.

The subsequently outlined Labradorian has been eliminated as a member of the time-series, and the rocks of the so-called 'Hastings Group' remain yet in a doubtful position, but with the promise that they may afford a clue to the true relations of the Grenville Series of the eastern and the Huronian of the western province of the Protaxis.

To what extent the above subdivisions of the Archæan may be legitimately employed in other parts of the continent, more or less remote from the Protaxis, remains largely a question for future investigation. In the southern part of New Brunswick, however, the resemblance of the Archæan to that of the typical region is so close that there can be little risk of error in applying the same classificatory names to it. The Fundamental Gneiss is there in contact with a series comprising crystalline limestones, quartzites, and gneissic rocks, precisely resembling those of the Grenville Series. Later than this is a great mass of more or less highly altered rocks, chiefly of volcanic origin, comprising felsites, diorites, agglomerates, and schists of various kinds, like those of the typical Huronian. The existence of this upper group correlatively with that representing the Grenville Series, constitutes an argument, so far as it goes, for the separateness of these two formations in the general time-scale. All these Archæan rocks of New Brunswick are distinctly unconformable beneath fossiliferous beds regarded by Matthew as older than Cambrian.

In the Cordilleran region of Canada, again, a terrane is found lying unconformably beneath the lowest rocks possibly referable to the Cambrian, evidently Archæan, and with a very close general resemblance to the Grenville Series. To this the local name Shuswap Series has been applied, and a thickness of at least 5,000 feet has been determined for it in one locality. It consists of coarsely crystalline marbles, sometimes spangled with graphite and mica, quartzites, gneisses, often highly calcareous or quartzose, mica schists, and hornblendic gneisses. With these is a much greater mass of gneissic and granitoid rocks, like those of the Fundamental Gneiss of the Protaxis, and the resemblance extends to the manner of association of the two terranes, of which, however, the petrographical details remain to be worked out.[1]

While it is true that a resemblance in lithological character, like that existing between the Grenville and Shuswap Series, far remote from each other geographically, may mean only that rocks of like composition have been subjected to a similar metamorphism, both the series referred to are separated above by an unconformity from the lowest beds of the Palæozoic, and there is thus sufficient evidence to indicate at least a probability of their proximate identity in the time-scale. In Scotland, an analogous series, and one apparently similarly circumstanced, seems to occur in the rocks of Gairloch and Loch Carron.[2]

Particular attention has been directed throughout to the southern part of the continental Protaxis in Canada. In this region it happened that the Archæan rocks and those resting upon them were originally studied under exceptionally favourable conditions, for ever since the great revolution which succeeded Huronian time, the region is one which has remained almost stable. Selwyn and N. H. Winchell have particularly insisted on the importance of the stratigraphical break which here defines the Archæan above. It is not everywhere so well marked, for in the Appalachian province and in the country to the south of the great lakes, in Wisconsin and Michigan, repeated subsequent earth-movements have flexed and broken the older strata against the base of the table-land of the Protaxis. It is not from these districts, subjected to more recent and frequent disturbance, that the ruling facts of an earlier time may be most easily ascertained. Much careful and conscientious work has been devoted to them, but it is largely, I believe, because of the attempt to apply, for purposes of general classification, the still unsettled and ever-changing hypotheses derived from such more complicated tracts that so much confusion has been introduced in regard to the Archæan and early Palæozoic rocks.

If the unconformity closing Archæan time in the vicinity of the Great Lakes had been observed only in that region, it might be regarded as a relatively local phenomenon; but subsequent observations, and more particularly those of the last few years, due to Bell, McConnell, Tyrrell, and Low, show that rocks evidently representing the Animikie and Keweenawan, and practically identical with those

[1] Cf. *Annual Report Geol. Sur. Can.*, 1888-89, p. 29 B.
[2] Cf. Geikie, *Ancient Volcanoes of Great Britain*, vol. i. p. 115.

of Lake Superior in general lithological character, recur in many places almost throughout the whole vast area of the Protaxis, on both sides of Hudson Bay, and northward to the Arctic Ocean, resting upon the Archæan rocks always in complete discordance, and lying generally at low angles of inclination, although often affected by great faults. The surface upon which these rocks have been deposited is that of a denudation-plane of flowing outline, not differing in any essential respect from that characterising parts of the same great plateau where there is no evidence to show that any deposition of strata has occurred since Archæan time. Mr. Low, indeed, finds reason to believe that even the great valleys by which the Archæan plateau of Labrador is trenched had been cut out before the general subsidence which enabled the laying down of Animikie rocks upon this plateau to begin. The area over which these observations extend, thus in itself enables us to affirm that the unconformity existing between the Animikie or Keweenawan (as the case may be) and the Archæan is of the first order.[1] It may be compared with that now known to occur between the Torridonian of Scotland and the underlying rocks there, and is evidenced by similar facts.

If the structural aspects of the Archæan rocks of the Protaxis are considered, the importance of this gap becomes still more apparent. We find long bands of strata referable to the Huronian and Grenville Series, occupying synclinal troughs, more or less parallel to each other and to the foliation of the Fundamental Gneiss, the strata, as well as the foliation, being in most cases at high angles, vertical, or even reversed. This structure is precisely that which would be discovered if a great mountain system, like that of the Alps, were to be truncated on a plane sufficiently low. Analogy thus leads to the belief that the Protaxis was originally, as Dana has suggested, a region of Appalachian folding, differing only from more modern examples of mountain regions of the same kind in its excessive width, which is so great as to render it difficult to conceive that crustal movements of sufficient magnitude to produce it could have occurred at any one period. It is thus, perhaps, more probable that successive and nearly parallel flexures of the kind, separated by long intervals of rest, piled range upon range against the central mass of the protaxial buttress subsequent to the Huronian period. In any case, the rugged mountain region brought into existence when the corrugation still evidenced by its remaining base occurred, was subsequently reduced by denudation to the condition of an undulating table-land such as has been named a 'peneplain' by W. M. Davis—a surface approximating to a base-level of erosion. All this was accomplished after the close of the Huronian period, and before that time at which the first beds of the Animikie were laid down correlatively with a great subsidence. It would be difficult to deny that the time thus occupied may not have been equal in duration to that represented by the whole of the Palæozoic.

If we approach this ruling unconformity from above, in the region of the Protaxis, we find the Animikie and Keweenawan rocks uncrystalline, except when of volcanic origin, and resembling in their aspect the older Palæozoic sediments, but practically without characteristic organic remains, so far as known. In order to bring ourselves into relation with the ascertained palæontological sequence, it is necessary to go further afield, and in so doing we lose touch, more or less completely, with the stable conditions of the Archæan platform, and are forced to apply indirectly such facts as it may be possible to ascertain in regions which have suffered more recent and complicated disturbance. It is thus not surprising that the taxonomic position of the Animikie and Keweenawan have been the subject of much controversy. It is not germane to the present discussion to enter at any length into this question, nor into the value of the unconformity which appears to exist between these two series. They have been classed collectively by Selwyn, N. H. Winchell, and others as Lower Cambrian, and are provisionally mapped as such by the Canadian Survey. It is believed to be more in accordance with the general principles of geological induction to refer these rocks above the great unconformity to the Cambrian, for the time being at least, than to unite them with the Huronian under any general term, or to erect a new system in which to place them. In so doing it has been assumed that the Cambrian is the lowest

[1] Cf. Selwyn, *Science*, Feb. 9, 1883.

system of the Palæozoic, but of late years the position has been taken by good authorities that the true base of the Cambrian is to be found at the *Olenellus* zone; ard while it appears very probable that, when fossils are found in the Animikie, they may be referable to this zone, the adoption of such an apparently arbitrary line certainly, for the time, must be considered as placing the Cambrian reference of the beds in question in doubt; but it does not interfere with a belief that if they should be found to be lower than Cambrian as thus defined, they may at least be considered as still in all probability Palæozoic.

The definition of the horizon of *Olenellus* as that of the base of the Cambrian is a question almost entirely palæontological, into which it is not proposed here to enter, further than to point out that it is only partially justified by what is known of North American geology. In the Atlantic province, and in the Appalachian region, there appears to be a very general physical break at about this stage, which it seems likely may correspond with the great unconformity at the base of the Animikie; but in the Rocky Mountain or Cordilleran region the *Olenellus* zone has been found high up in a series of conformable and similar sediments, coinciding with no break, and from these lower sediments some organic forms have been already recovered, but not such as to indicate any great diversity in fauna from that of the recognised Cambrian. Similarly, in one part of eastern Canada, Matthew has lately described a fauna contained in what he names the Etcheminian group, regarded by him as earlier than the *Olenellus* zone, but still Palæozoic. Recent discoveries of a like kind have been made in other parts of the world, as in the Salt Range of India. These facts have only last year been particularly referred to by Mr. Marr in his address to the Section.

The general tendency of our advance in knowledge appears, in fact, to be in the direction of extending the range of the Palæozoic downward, whether under the old name Cambrian, or under some other name applied to a new system defined, or likely to be defined, by a characteristic fauna; and under Cambrian or such new system, if it be admitted, it is altogether probable that the Animikie and Keweenawan rocks must eventually be included.

In other words, the somewhat arbitrary and artificial definition of the *Olenellus* zone as the base of the Cambrian, seems to be not only not of world-wide application, but not even of general applicability to North America; while, as a base for the Palæozoic Æon, it is of still more doubtful value. In the Cambrian period, as well as in much later geological times, the American continent does not admit of treatment as a single province, but is to be regarded rather as a continental barrier between two great oceanic depressions, each more or less completely different and self-contained in conditions and history—that of the Atlantic and that of the Pacific. On the Atlantic side the *Olenellus* zone is a fairly well-marked base for the Cambrian; on that of the Pacific it is found naturally to succeed a great consecutive and conformable series of sediments, of which the more ancient fauna is now only beginning to be known.

In thus rapidly tracing out what appears to me to be the leading thread of the history of the pre-Cambrian rocks of Canada, and in endeavouring to indicate the present condition of their classification, and to vindicate the substantial accuracy of the successive steps taken in its elaboration, many names and alternative systems of arrangement proposed at different times, by more or less competent authorities, have been passed without mention. This has been done either because such names and classifications appear now to be unnecessary or unfounded, or because they relate to more or less local subdivisions of the ruling systems which it is not possible to consider in so brief a review. This has been particularly the case in regard to the much-disputed region to the south of Lake Superior, out of which, however, after some decades of complicated and warring nomenclature, a classification, trending back substantially to that originally established and here advocated, is being evolved (albeit under strange names) by the close and skilful stratigraphical work in progress there.

It has also been my object, in so far as possible, by omitting special reference to divergent views, to avoid a controversial attitude, particularly in respect to matters which are still in the arena of active discussion, and in regard to which

many points remain admittedly subject to modification or change of statement. But in conclusion, and from the point of view of Canadian geology, it is necessary to refer—even at the risk of appearing controversial—to the comparatively recent attempt to introduce an 'Algonkian System,' under which it is proposed to include all recognisable sedimentary formations below the *Olenellus* zone, assumed for this purpose to be the base of the Cambrian. If in what has already been said I have been able correctly to represent the main facts of the case—and it has been my endeavour to do so—it must be obvious that the adoption of such a 'system' is a retrograde step, wholly opposed, not only to the historical basis of progress in classification, but also to the natural conditions upon which any taxonomic scheme should be based. It not only detaches from the Palæozoic great masses of conformable and fossiliferous strata beneath an arbitrary plane, but it unites these, under a common systematic name, with other vast series of rocks, now generally in a crystalline condition, and includes, as a mere interlude, what, in the region of the Protaxis at least, is one of the greatest gaps known to geological history. In this region it is made to contain the Keweenawan, the Animikie, the Huronian, and the Grenville Series, and that without in the least degree removing the difficulty found in defining the base of the last-mentioned series. It thus practically expunges the result of much good work, conducted along legitimate lines of advance during many previous years, with only the more than doubtful advantage of enabling the grouping together of many widely separated terranes in other districts where the relations have not been even proximately ascertained. It is in effect, to my mind, to constitute for geology what was known to the scholastic theologians of a former age as a *limbo*, appropriate as the abode of unjudged souls and unbaptized infants, that might well in this case be characterised as 'a limbo large and broad.'

It is not intended to deny that there may be ample room for the introduction of a new system, or perhaps, indeed, of an entire Geological Æon, between the Huronian, as we know it in Canada, and the lowest beds which may reasonably be considered as attaching to the Cambrian, or even to the Palæozoic as a whole. On the contrary, what has already been said will, I think, show that in the region of the Protaxis we might very reasonably speak of an 'Algonkian hiatus,' if we elect so to call it. Elsewhere it will undoubtedly be possible, sooner or later, to designate series of rocks laid down during the time represented only by orogenic movements and vast denudation in the province here more particularly referred to, but before any general systematic name is applied to such terranes they should be defined, and that in such a way as to exclude systems already established as the result of honest work.

It seems very likely, for instance, that the Grand Cañon Series, as last delimited by Walcott, separated by unconformities from the Tonto Cambrian above and the probably Archæan rocks below, may be referable to such an intermediate system; but here it may be noted, in passing, that the attempt to apply the new term 'Algonkian' in this particular Western region, has led to the inclusion under that name of a great unconformity below the Grand Cañon Series, much resembling the post-Huronian break in the Lake Superior district.

For such unclassed rocks, wholly or in large part of sedimentary origin, the Canadian Survey has simply employed the term pre-Cambrian, involving for certain regions a frank confession of ignorance beyond a certain point. Indefinite as such a term is, it is believed to be more philosophical than to make an appearance of knowledge not borne out in fact, by the application of any systematic name not properly defined.

Although it would be unsuitable, at the close of this address, to introduce the old controversy respecting the Cambrian and Silurian, it may be noted that the ethical conceptions and many of the principles involved in that discussion still apply with undiminished value, and much of its literature may be re-read to-day with advantage. More particularly I would allude to Sedgwick's inimitable and now classic introduction to McCoy's 'Palæozoic Fossils,' one passage in which, paraphrased only by the change of names involved in that and in the present discussion, may be read as follows:—'"*Est Jupiter quodcunque vides*" was once said

by Dean Conybeare in mockery of the old despotic rule of the name Greywacké. A golden age of truth and reason, and slow but secure inductive logic, seemed to follow, but the jovial days of a new dynasty are to spring up, it seems, under a new name not less despotic than the one which had ruled before it. If all the [sedimentary] rocks below the [*Olenellus* zone] are to pass under one name, let us cling to the venerable name Greywacké. It can do no mischief while it describes things indefinite, simply because it is without meaning. But the name [Algonkian], if used in the same extended sense, is pregnant with mischief. It savours of a history that is fabulous; it leads us back to a false type; it unites together as one systems that nature has put asunder.'

The following Papers and Reports were read :—

1. *Some Typical Sections in South-western Nova Scotia.* *By* L. W. Bailey, *Ph.D.*, *University of New Brunswick.*

The sections figured and described in this paper are intended to represent, in summary form, the results of recent investigations, made under the direction of the Geological Survey of Canada, into the geological structure of South-western Nova Scotia.

They are five in number, the first being in Queen's County, along the course of the Port Medway River, showing the succession and foldings of the Cambrian rocks in their ordinary form, together with their relations to the great granite axis of the Province, and the occurrence of auriferous deposits. The second is in Yarmouth County, exhibiting the rocks of the same system in a more metamorphosed condition, and showing also that the rocks about the city of Yarmouth, formerly regarded as Archæan, are also a portion of the Cambrian system. The third section is in Digby County, exhibiting the parallelism of the Cambrian succession north of the granite axis, with the same on its southern side. A fourth section, in Annapolis County, illustrates the relation to the Cambrian rocks, and to the granite, of the fossiliferous and iron-bearing Eo-Devonian rocks of Bear River, Nictau, and Torbrook. A fifth section may also be given, showing the structure and relations of the stratified and igneous rocks, usually regarded as Triassic, of the Annapolis Valley.

All the sections are diagrammatic, but based on actual surveys.

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2. *Problems in Quebec Geology.* *By* R. W. Ells, *LL.D.*, *F.R.S.C.*, *of the Geographical Survey of Canada.*

This paper is a brief review of the geological work done in the province of Quebec since the appearance of Dr. Bigsby's first paper on the geology of the province in 1827. It contains a short statement of the conclusions arrived at from time to time by the various workers in this field regarding the structure of the rock formations east of the St. Lawrence, as well as of the Laurentian complex to the north of that river. A summary of the latest views reached from the detailed study of these areas during the last fifteen years, which has appeared in the last volume of the Geological Survey's report, is also presented.

In regard to the structure of the older crystallines north of the St. Lawrence and Ottawa Rivers, it may be said that the opinion once held, that these rocks were originally of sedimentary origin, has now been greatly modified. The Laurentian rocks of Logan are now divided into two great groups. Of these, the lower is essentially a gneiss formation, and may be styled, for the sake of distinction, the Fundamental Gneiss. This is clearly older in point of time than the series of crystalline limestones, quartzose grey gneisses, and quartzite with which they are often so intimately associated as to render the determination of their true relations in the field difficult, but which at other points are clearly situated above the lower gneiss formation.

These newer gneisses and limestones which have been styled by Logan the 'Grenville Series' are, without doubt, for the most part of sedimentary origin, though they are invaded in all directions by masses of granite, greenstone, and other forms of igneous rock. As for the Fundamental Gneiss, also once supposed to be largely of sedimentary origin, it has been very conclusively demonstrated, chiefly through the agency of the microscope, that this is for the most part at least an altered igneous rock, and that the supposed bedding planes owe their existence to other causes than those of sedimentation.

The original upper Laurentian division, which included the great area of the Anorthosite rocks, also supposed at one time to represent altered sedimentary deposits, has been removed from the position it once occupied, since it has been proved, both by the evidence in the field and in the laboratory, to be of igneous origin and subsequent to the deposition of the limestone and quartzite series with which it is associated, so that the Grenville Series, according to the earlier view as to the succession of strata, may now be taken to represent the upper portion of the Laurentian system.

It may also be assumed to represent the lowest division of the clastic or sedimentary rocks in Canada. The relations of these to the rocks which have been styled the 'Hastings Series' in Ontario are such that they may, in part at least, be regarded as portions of the same series which have been described in different portions of the field under different names; but whether these be regarded as belonging to the Laurentian or Huronian systems is of small moment so long as their true relationship to each other and to the underlying Fundamental Gneiss is clearly understood.

To the east of the St. Lawrence the old dispute as to the age of the fossiliferous rocks near the city of Quebec, as well as of their relations to the crystalline schists of the mountain area in the interior of the province, may now be considered as satisfactorily settled. The former hypothesis by which the crystalline schists were regarded as the equivalents, in point of time, of the fossiliferous sediments of the St. Lawrence Valley has been clearly shown to be unfounded, and the schists of the Sutton Mountain area are now assigned to the Huronian system, or are at least beneath the lowest Cambrian of the district. The relative position of the several divisions of the fossiliferous Quebec group has also been ascertained, and it is now established that the Sillery division is situated stratigraphically beneath the Lévis, instead of being, as was at one time supposed, above it. As regards the age of the several divisions of the Quebec group (fossiliferous) it may be said that the Lévis is the apparent equivalent of the Calciferous formation, and that in its upper portion it approaches the Chazy; while the upper portion of the Sillery is the apparent equivalent of the Potsdam Sandstone formation. Between the Upper Sillery and the great mass of the rocks which have been referred to this division, there is a fault of considerable magnitude, so that the lower portion of the Sillery presumably includes rocks which have been elsewhere classed as Cambrian, and these may extend as low as the Paradoxides zone or division of that system.

The areas of black slate and limestone, which, in the General Report for 1863, were regarded as beneath the crystalline schists, and referable to the Potsdam formation, have been determined, on the evidence of the contained fossils, to be much newer, and to be in fact the equivalents of the lower portion of the Trenton formation; and to this horizon may also now be assigned the greater portion of the strata in the city of Quebec. Here, however, there are a number of anticlinal folds, and the presence of certain fossils, similar to those obtained from the Lévis beds, indicates that along some of these folds beds of that horizon may be found. The same age may be assigned to the great extension of the black slates and limestones which occur at intervals along the south shore of the St. Lawrence, nearly to the extremity of the Gaspé Peninsula, and which appear to dip beneath the strata of the Sillery formation at many points.

In regard to the use of the term Potsdam a distinction must now be made between the Potsdam formation and the Potsdam Sandstone. The latter has been clearly proved in Canada to be the lower portion of the Calciferous formation, and is not separable from it, while there is a manifest break between this and the

lower beds, or the Cambrian proper. The term Potsdam formation in Canadian geology was a comprehensive one like the term Cambrian, and like it included all between the Calciferous formation and the Huronian. The indiscriminate use of the terms has led to much confusion, and as the divisions of the Cambrian have now been properly determined the expression Potsdam formation has practically no meaning in Canadian geology.

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3. *Report on Life-Zones in the British Carboniferous Rocks.*
See Reports, p. 296.

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4. *The Stratigraphic Succession in Jamaica.*
By ROBERT T. HILL, *Geologist, United States Geological Survey.*[1]

This paper gives results of a series of stratigraphic, petrographic, and topographic studies made in the island in the years 1895, 1896, and 1897, under the auspices of Professor Alexander Agassiz, for the purpose of determining a typical West Indian section which would serve as a basis for comparison with the other West Indian localities.

The work of the officers of the British Survey and other previous observers was taken as a basis and advanced by critical studies and correlations of other type localities, and by observations upon the new exposures revealed in the recent highway and railway improvements. A new classification and nomenclature of the rocks is proposed, and the sequence of the geologic events in Jamaica history is outlined and interpreted. Petrographic data by Cross and palæontologic determinations by Agassiz, Dall, Vaughan, and others are incorporated in the paper.

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5. *Preliminary Notice of some Experiments on the Flow of Rocks.*
By FRANK D. ADAMS *and* JOHN T. NICOLSON, *McGill University, Montreal.*

These experiments aim at ascertaining whether it is possible, by subjecting rocks artificially to pressure under the conditions which obtain in the deeper parts of the earth's crust, to produce in them the deformation and cataclastic structures exhibited by the folded rocks of the interior of mountain ranges or of the older formations of the earth.

Three factors contribute toward bringing about the conditions to which rocks are subjected in the deeper parts of the earth's crust: (1) Great pressure from every direction; (2) high temperatures; (3) action of percolating waters. In the present experiments the attempt has been made to reproduce only the first of these conditions, in subsequent experiments the endeavour will be made to reproduce all three of them.

The experiments have been made chiefly with pure Carrara marble. Columns of the marble 2 centimetres, and 2½ centimetres in diameter, and about 4 centimetres in length, were very accurately turned and polished. Heavy wrought iron tubes were then made, imitating the plan adopted in the construction of ordnance, by rolling long strips of Swedish iron around a bar of soft wrought iron and welding the strips to the bar as they were rolled around it. The core of soft iron composing the bar was then drilled out, leaving a tube of welded Swedish iron 6 millimetres thick, so constructed that the fibres of the iron run around the tube instead of being parallel to its length. This tube was then very accurately fitted on to the column of marble. This was accomplished by giving a very slight taper to both the column and the interior of the tube, and so arranging it that the marble would pass only about halfway into the tube when cold. The tube was

[1] By permission of Professor Agassiz, under whose auspices the researches were made.

then expanded by heating, so as to allow the marble to pass completely into it, and leave about 3 centimetres of the tube free at either end. On allowing the tube to cool a perfect contact between the iron and marble was obtained, and it was no longer possible to withdraw the latter. Any very slight failure to fit at any point, if such a failure existed in any case, was rendered harmless by the fact that under a comparatively low pressure the limestone is found to be sufficiently elastic not only to fill up any such minute space, but even to stretch the tube, and, on the pressure being relieved, to contract again to its original form, so that it will drop out of the tube which has been thus enlarged. Into either end of the tube containing the small column an accurately fitting sliding steel plug was inserted, and by means of these the marble was submitted to a pressure far above that which would be sufficient to crush it if not so inclosed. The machine employed in obtaining the pressure was so arranged that the pressure might be maintained for weeks, or even months, if required. Under these circumstances the conditions of pressure to which the marble is subjected are those in the 'zone of flow' of the earth's crust—those, namely, of a pressure above that of its elastic limit, while yet unable to break in the ordinary manner owing to the tube which confines it having a still higher elastic limit. Under the pressure, which was applied gradually and in some cases continued for several weeks, the tube was found to slowly bulge until a very marked enlargement of the portion surrounding the marble had taken place. The tube was then cut through longitudinally by means of a milling machine along two lines opposite one another.

The marble within, however, was still firm, and held the respective sides of the iron tube, now completely separated, so tightly together that it was impossible without mechanical aids to tear these apart. By means of a wedge, however, they could be separated, splitting the marble through longitudinally. The column in one experiment was reduced from 40 millimetres to 21 millimetres in height. The deformed marble differs from the original rock in having a dead white colour, the glistening cleavage faces of calcite being no longer visible, and although not so hard as the original rock, it is still firm and compact, and especially so when its deformation has been carried out very slowly. No accurate measurements as to its strength have yet been made, but it will withstand a sharp blow, and fragments of it, weighing 10 grams, have been allowed to fall through a height of over $2\frac{1}{2}$ metres (8 feet) on to a wooden platform, from which it rebounded without breaking. Thin sections of the deformed marble, when examined under the microscope, show that the calcite individuals composing the rock have in many cases been twisted and flattened, and in the majority of cases a very fine polysynthetic pressure-twinning has been induced in them, with movement along gliding planes, as well as several other structures seen in nature in highly deformed rocks.

The experiments therefore show that limestone, even when dry and at ordinary temperatures, does possess a certain degree of plasticity, and can be made to 'flow,' the movements set up developing many structures which are characteristic of rocks which have been squeezed or folded in the deeper portions of our earth's crust.

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6. *The Former Extension of the Appalachians across Mississippi, Louisiana, and Texas.*[1] *By* John C. Branner, *Ph.D., Professor of Geology, Stanford University.*

I. The Ouachita anticline is the structural equivalent of the Cincinnati-Nashville arch: this fold continues westward through the Arbuckle Mountains in Indian Territory and to the Wichita Mountains in Southern Oklahoma Territory.

II. The Coal Measures drainage of the Illinois-Indiana-Kentucky basin flowed westward through the Arkansas valley into a Carboniferous mediterranean sea.

III. The drainage of the Coal Measures region south of the Ouachita anticline flowed westward, and entered this sea north of the Texas pre-Cambrian area.

[1] Published *in extenso* in the *American Journal of Science*, November 1897, iv. 357–371.

IV. The drainage of both the Arkansas and Texas Carboniferous areas was reversed about the end of Jurassic times, when orographic movements over South-east Arkansas, Eastern Texas, Louisiana, and Mississippi submerged the former extension of the Appalachian watershed, and admitted the early Cretaceous sea across the Palæozoic land as far north as Southern Illinois.

V. This depression was not a deep one (Hilgard[1]) and did not all occur at one time, for there have been subsequent disturbances of a more or less similar nature in the same region.

VI. The evidences of this depressions are—

1. The reversed drainage of the Arkansas valley.
2. The reversed drainage over the Carboniferous area of Central Texas.
3. The submerged eastern end of the Ouachita uplift of Arkansas.
4. The eastern slope of the peneplain of the Ouachita region.
5. The direction of the faults and folds near the eastern exposure of the Lower Coal Measures in Arkansas.
6. The great fault through Texas near the Tertiary border having a down-throw of 1,000 to 1,500 feet on the south and east side.
7. Eruptive rocks accompanying the Texas fault and the Tertiary border through that State and Arkansas to the Arkansas River.
8. Hot springs near the same line.
9. Faults in Alabama with a down-throw of 10,000 feet or more on the north-west side.
10. The thickness of the Cretaceous and Tertiary sediments over the depressed area—from 4,000 to 10,000 feet.

VII. The south-western or Central Texas end of the Appalachian land areas was formerly covered by Cretaceous sediments, but it has since been uncovered by erosion; further east it is still concealed.

VIII. The Carboniferous beds uncovered in Texas all belong to the Upper Coal Measures, except at the edge of the synclinal trough; it is inferred that a greater thickness is still covered.

IX. The character of both the Silurian and Lower Coal Measures sediments of the Ouachita uplift show that they came from the south, so that the land area must have been in that direction during Palæozoic times.

X. The sea occasionally invaded both the Arkansas and Texas synclinal troughs during Coal Measures times, but coal-forming conditions obtained in the Texas syncline later than in the Arkansas basin.

XI. The Tertiary depression was probably more marked on the Arkansas than on the Tennessee side of the embayment: this is suggested by the Cretaceous border being concealed by thin Tertiary deposits in Arkansas, while in Tennessee, Mississippi, and Alabama it is exposed in a broad belt.

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7. *Report on the Investigation of a Coral Reef.* See Reports, p. 297.

FRIDAY, AUGUST 20.

The following Papers were read:—

1. *A Group of Hypotheses bearing on Climatic Changes.*[2]
By T. C. Chamberlin, *Professor of Geology in the University of Chicago.*

A computation of the several constituents of the atmosphere and of the rate at which they are being consumed in the alteration of the surface rocks indicates that in a comparatively few thousand years the carbonic acid of the air will be exhausted if there is no compensating source of re-supply. The ocean contains about 18 times

[1] *Amer. Jour. Sci.*, 1874, vol. cii. p. 394.

[2] *Jour. of Geol.* (Chicago), vol. v. p. 653.

as much carbonic acid as the air, but even if this were all available the maintenance of conditions congenial to life would still be geologically short. A broad comparison between the atmospheres of the palæozoic and the cainozoic times fails to give clear proof of radical differences. The magnolia flora in North Greenland in tertiary times indicates scarcely less wide distribution of warm climate than the life of the same region in palæozoic times. The glaciation of India, Australia, and South Africa at the close of the palæozoic era is even more marvellous than that at the close of the more recent era. The salt deposits of middle latitudes, especially of Michigan and New York, imply as great aridity as we find at any time since. The early life does not give clear proof of more carbonic acid in the air than the later life. The tardiness of land life may be accounted for otherwise.

But the amount of carbonic acid taken from the air by carbon-bearing deposits is estimated variously at 12,000 to 150,000 times that now in the air. At least 8,000 or 10,000 times the present amount of carbonic acid has quite certainly been taken out since air-breathing life began. This forces the question whether all this carbonic acid, or any major part of it, was ever in the air at any one time. The alternative is to suppose the air to have been fed as well as robbed during all the geological ages. The current view of a former vast, dense, hot and moist atmosphere has, however, been derived more from theories of the earth's origin and primitive state than from computation of the material removed from it. The belief in the gaseous origin of the earth naturally carries with it the doctrine of a primitive hot atmosphere. The belief in a molten condition naturally led also to the view that the ocean was once all in the atmosphere. This does not, however, rigorously follow. Much of the ocean may have been accumulated since, but I venture to question both the primitive molten state and the inferences drawn from it. There is still some ground to doubt the nebular hypothesis, and to entertain some phase of the meteoroidal hypothesis, but even if the nebular theory be followed as far as the separation of the earth-moon ring, a molten state of the earth may not necessarily follow. The vast size, the tenuity and the high temperature of the supposed gaseous ring suggest its speedy cooling to the form of a ring of discrete solid particles like the rings of Saturn. Moreover, a study of the velocity of the gaseous molecules and the limitations of the power of celestial bodies to hold them, makes it extremely doubtful whether such a ring could control its own hot gases. The same line of study even makes it doubtful whether a molten earth could hold to itself a vast vaporous atmosphere such as the ocean would form. The great velocity of the gaseous molecules at the temperature of a molten earth, and the reduction in the influence of gravity by the high centrifugal force, combine to render the case a somewhat critical one.

If the matter of the supposed earth-moon ring became cooled to solid particles while in the ring form, or if the earth were formed by the collision of meteoroidal matter, the temperature of the surface of the earth at any given time would depend on the rate and violence of the infall. A cold earth is theoretically as possible as a hot one. Reasons may be assigned why the temperature was likely to be low.

A sketch was given of the hypothetical growth of the earth by the ingathering of the solid particles of the supposed earth-moon ring, in the course of which it was shown that the peculiar constitution of such a body, when it reached the size of the moon, would be favourable to explosive eruptions and liable to give rise to craters like those of the moon. The internal heat necessary would come from the self-condensation of the growing globe. Computations were cited to show that this was adequate. The gases and vapours involved were attributed to atmospheric material carried in by the ingathering particles. When the mass reached a size large enough to hold an atmosphere, this size being probably about that of Mercury, or a little larger, it would pick up atmosphere from without and would hold the gases and vapours emanating from within, and thus the atmosphere as an envelope would begin. As soon as it acquired sufficient extent to retain the heat of the sun, the modern phase of the history of the earth would begin, and in time the conditions for the presence of life would be reached. This makes the introduction of life possible at a very much earlier stage than the current hypotheses, and gives ample time for the most strenuous demands of theoretical biology. The

shrinkage of the earth gradually, owing to its own gravity, would give a sufficient amount of contraction to explain not only the phenomena of mountains and archæan crumplings, but of plateaux, continents, and ocean basins. Computation shows that the internal heat generated by the time the earth reached its maturity would be ample to explain the present internal heat, and account for much loss during geological ages.

This is a departure from the common view of the history of the atmosphere in supposing it to begin as a tenuous envelope, and be subject both to enrichment and depletion during all its subsequent history. The supply from within is very imperfectly known. The air and ocean together are only about one-fiftieth of 1 per cent. of the earth's mass. The increase of the atmosphere from without is almost wholly a matter of conjecture.

The emanations from within would doubtless be more abundant at times of igneous extravasation and of the disruption of the crust than at other times, so that the supplies to the atmosphere would vary according as the average of these conditions varied. The impoverishment of the atmosphere, particularly in respect to its carbonic acid, was probably dependent very largely upon topographic states. When the land was elevated the underground water-level was relatively deep beneath the surface, and the penetration of aerated waters below was also deep, and the alteration of the rocks went on relatively rapidly. When the land was depressed or cut down to an approximate base-level the underground water surface was shallow, and the penetration of aerated waters below that was also shallow, and the change of the rocks was slow. Whenever, therefore, the land on an average stood high, the impoverishment of the atmosphere went on rapidly; whenever it was low, slowly. Combining this with the irregularities of supply, it appears that enrichment and impoverishment would generally run together and give, on the whole, a somewhat uniform atmosphere; but in the nature of the case the two were not strictly concurrent, and as a result at times there was enrichment, and at times depletion of the atmosphere. From these it is held that great climatic changes would arise. Scantiness of carbonic acid would be correlated with cold temperatures, as maintained by Tyndall and others. The great periods of cold temperature should therefore follow at some distance the great periods of elevation of the crust of the earth. The recent great glaciation followed at a notable interval the great uplifts of the tertiary era. The great glaciation of India, Australia, and South Africa came at about the time of the great disturbances closing the palæozoic era, but the precise relation cannot be positively stated. There seem to be other correspondences between the laws here laid down and the great climatic episodes of past geologic times.

Another source of atmospheric loss arises from the removal of carbonic acid by plants, and the failure of this to be returned by decay or the action of animals. It is estimated that the present annual growth of vegetation is sufficient to consume all the carbonic acid in the air in one hundred years if there were no return. It is believed that cold temperature would check the decay of vegetation and prevent, in part, the return of the carbon to the atmosphere, and this would tend to impoverish it.

Tyndall suggested, fifty years ago, that the glacial periods might be due to scantiness of carbonic acid in the atmosphere. Dr. Arrhenius has recently made elaborate computations on the subject, and has reached the conclusion that the removal of from 38 to 45 per cent. of the carbonic acid would bring on such a glaciation as occurred in the ice age, and that an increase of two and a half to three times the present carbonic acid would bring on a mild temperature, like that of tertiary times. This view leaves the oscillations of the glaciation to be accounted for. It is suggested that a rhythmical movement in the feeding and robbing of the atmosphere would result from the action of the ocean and of the organic cycle. The ocean, when cold, absorbs more carbonic acid than when warm, and hence, instead of coming to the rescue of the atmosphere when robbed of its carbon dioxide by the rocks, it was disposed to hold its carbonic acid, and perhaps even turn robber itself. At the same time, the vegetation was less subject to decay, and a smaller part of the carbon was returned to the air. By the combination of

these agencies the impoverishment of the atmosphere was hastened, and the epoch of cold precipitated.

But when glaciation spread over the crystalline areas whose alterations were the chief source of depletion, the abstraction of the carbonic acid was checked, and if the supply continued, the re-enrichment would begin and warmth return. With returning warmth the ocean would give up its carbonic acid more freely, and the accumulated vegetable matter would decay, adding its contribution of carbonic acid and accelerating the re-enrichment of the atmosphere. But when again the ice disappeared and the crystalline areas were exposed to alterations the depletion would be renewed, and so the rhythmical movement would continue until the land was lowered or the general conditions changed.

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2. *Distribution and Succession of the Pleistocene Ice Sheets of Northern United States. By* T. C. Chamberlin, *Professor of Geology in the University of Chicago.*

In this communication the author presented a synopsis of the leading events in the history of the Pleistocene as determined from studies of Glacial deposits throughout Northern United States from the Rocky Mountains to the Atlantic Coast, and from the mouth of the Ohio northward to the Canadian border. The several ice sheets determined from their products were defined, and the extent of each was indicated; while the effect of Glacial action on topographic configuration and the geographic features of the country was developed.

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3. *On the Glacial Formations of the Alps. By* Professor A. Penck.[1]

The former glaciation of the Alps resembled very much that of British Columbia and Alaska of to-day. The valleys were filled with glaciers, which poured into the Piedmont region, forming here large ice-lobes. The borders of these ice-lobes are formed by terminal moraines; in the interior occur drumlins with a radial direction, and depressions filled with water forming lakes, or with alluvial deposits forming peat-mosses or gravel-flats.

The glacial formations consist of true moraines and fluvioglacial deposits. Three different formations of this kind can be distinguished, the older being weathered below the younger. Judging from the thickness of the decomposed parts, the relation of the duration of the postglacial and the two interglacial epochs may be estimated as 1 : 4 : 6. The duration of the postglacial time cannot have been less than 20,000 years; the duration of both interglacial epochs, therefore, appears to have exceeded 200,000 years; the total length of the great ice age, with its glacial and interglacial epochs was, judged by the deposits of the Po plain, 500,000 years. Interglacial sections prove that in the interglacial epochs the glaciers retired to the remote corners of the mountains. The loess is the characteristic formation of the Alpine interglacial epochs. Its development is in favour of Baron v. Richthofen's æolian hypothesis, for the loess is confined to the central European districts of the Alps, and is wanting in the Mediterranean climate. But it is also probable that the material of the loess is of fluvioglacial origin. The older glacial deposits of the Alps have experienced a slight folding; parallel to the strike of the Western Alps they describe a succession of synclines and anticlines.

All Alpine lakes lie within the limits of the last glaciation; their origin, however, is a very complex one. They are, in general, deformed valleys, deepened and widened by the ice, and dammed by its moraines.

The postglacial epoch appears short in comparison with the interglacial epochs, and if there occurred times of readvance of the ice, which are probably indicated by terminal moraines in the valleys, they were less than the three glacial epochs. There is abundant evidence for the existence of man during the last glacial and the last interglacial epoch; its antiquity in Europe can be estimated as about 150,000 years.

[1] The paper will be published in the *Journ. of Geology*, Chicago.

4. *On the Åsar of Finland.* *By* P. Kropotkin.

These observations on the åsar, or eskers, of Finland were made in 1871. Many researches have been made since by Finnish geologists; but although the glacial origin of the åsar is now firmly established, their mode of formation in connection with the ice-sheet still remains uncertain.

The chief point which appears in regard to the åsar of Finland and Sweden is that they follow the same lines as were followed by the ice-cap in its southward and south-eastward movement. While taking no heed of important orographical features, they take into account, like glacial striæ, minor depressions and elevations, showing that the ice always followed the lines of least resistance.

The main Swedish åsar descend from the highlands; they spread next upon an elevated plain, 100 to 200 feet high; then they descend to the Mälar depression, cross it, and finally creep over the hilly tracks in the south of Lake Mälar.

At the time of the author's visit to Sweden, the ås of Upsala was cut through its whole width at Upsala, for making a new road. It consists of a core, made up of totally unstratified, unwashed, and unsorted gravel, composed of round, angular, and sub-angular stones, from a few inches to several feet in diameter, mixed with sand and finest mud. This gravel is exactly similar to the bottom moraine in the neighbourhood, only containing a slightly greater proportion of limestone boulders brought from Gefle. This core is covered with a mantle of washed, stratified, and sorted gravels, sands (ripple-marks), and clays, with Baltic shells.

The åsar of Finland, represented on an orographic map, all run N.W. to S.E. One of them, the Pungaharju, was described, to show the orographic features of a big ås. The Kangasala ås, in West Finland, occupies a position which makes of it a sister ås to the Swedish åsar on the western shore of the Gulf of Bothnia. It is a typical ås, ninety-five miles long (twenty-two miles explored). It has all the characters of a longitudinal moraine, partly destroyed by the lakes and covered with sands and gravels which were washed by water and were deposited on the old shores of a lake which reached a higher level than is now reached by Lake Päjäne. The morainic core consists of a typical kross-stensgrus, in which immense scratched boulders are scattered.

Of later Finnish explorers, Wiik (1876), Gylling (1881), and Lederholm (1889) consider it also as a moraine, modified by water in its superficial layers; while Berghell (1892) is inclined to consider it as the produce of a glacial river.

The ås of Yväskylä bears the same character; while along the Tammerfors-Helsingfors railway the ås of Ryttilä was found to have been largely digged out as a ballast-pit. The washed and sorted gravel was taken away as ballast; but the till (which gives bad ballast owing to its contents of fine glacial mud) was left intact at the bottom, thus showing that the core of the ås is of morainic origin. The same was observed in the ås at Dickursby.

The conclusions to be drawn from these facts, taken out of many others observed by the author, are:—A strict distinction must be made between the *core* of an ås and its *mantle.* They are of distinct origin. The latter is always due to the action of water (rivers, lakes, or the sea), while the core, whenever access could be found to it, was invariably of morainic origin. Always it was found to consist of unwashed and unstratified till, and never of fluviatile deposits. This core is often buried under a thick sheet of water-deposits, and occasionally it lies even *beneath* the level of the surrounding plains. It must have the same origin as the drumlins, horse-backs, cames, &c., which are elongated hillocks formed in the bottom moraine, parallel to the motion of ice, and always accompany åsar. From the geological survey of Sweden it appears that the *bi-åsar* (small tributaries of the big åsar) often are such drumlins (*kross-åsar*); and while the Rongedala ås is described as a *rullsten*-ås in its lower parts, it is represented as of morainic origin in its upper parts.

We cannot say yet in which way these morainic ridges were formed, whether under, or within, or on the surface of, the ice-cap; but the åsar can safely be taken as *longitudinal moraines, superficially modified by water*. It is also very possible that the main Swedish åsar and the Kangasala ås were side morainic deposits of the lobes

of the ice-cap. But it is equally possible that similar morainic ridges may arise *under* the ice-cap, or within it.

At any rate, it seems almost impossible to explain the formation of åsar by river action. The cores of the Kangasala and Yväskylä åsar, with their immense scratched boulders, certainly *have not been deposited by rivers.* Nor the unstratified, unwashed, and unsorted core of the Upsala ås. This latter, which runs from a level of 500 feet to 120 feet, next raises to a level of 207 feet, descends to Lake Mälar in the level of the sea, and creeps again to a level of 180 feet, cannot have been made by a river. Even under the ice a river would mine its channel in the line of least resistance (eastwards in this case), instead of running uphill. No river could, moreover, have so steady a channel, a few hundred feet wide, as to make such a ridge; it would have changed its channel in the course of time in the ice as well, just as it does it in a rocky bed.

The latest researches of Finnish geologists, showing the existence of two *frontal moraines* of the ice-cap, nearly parallel to the northern shore of the Gulf of Finland, and probably of a third further north (about Kuopio) were next referred to, as a parallel to the frontal moraines discovered in America.

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5. *The Chalky Boulder-clay and the Glacial Phenomena of the Western-Midland Counties of England.*[1] *By* H. B. Woodward, *F.R.S.*

The general distribution of the Chalky Boulder-clay is first stated, and its limits in Southern and Western England defined. The author then deals with certain phenomena of especial interest, such as the wide dispersal of the chalky detritus in the drifts, the disturbance of the underlying strata, the occurrence of large blocks or 'cakes' of the local formations among the glacial deposits, and the intercalation of sand and gravel with the boulder-clay.

In the West-Midland counties, the glacial phenomena of which have not yet been thoroughly examined, there is a marginal area bordering the strongly glaciated regions to the east and north-east. This has not been affected by the later stages of the Glacial period, as the Chalky Boulder-clay is succeeded by modified drift in the form of valley gravels and loam, with the remains of mammoth and associated fossils, which merge into the estuarine and marine deposits of the Severn Valley. In sketching the probable southern and western limits of the Chalky Boulder-clay in this region, the author remarks on the absence of drift from certain elevated tracts as indicating that the land-ice may have been locally arrested by them and divided into lobes and tongues which invaded the lower ground. Previous to this glaciation the main features of the country seem to have been as at present, but there was no doubt a thick covering of weathered rock and rubble on the surface, and this material would be readily frozen into the base of a sedentary ice-sheet. In general the chief effect of the ice has been to degrade the surface features rather than to efface them.

The glaciation does not seem to have affected the Cotteswold Hills, which are flanked with thick accumulations of local rubble, explicable as the result of the disintegration and redistribution of the surface layers during alternate frost and thaw, as suggested by Witchell and Lucy; Edgehill also appears locally to have arrested the land-ice.

Although the chalky ingredients of the Chalky Boulder-clay are present over wide areas, there is much local variation in the other material, according to the nature of the underlying rocks. The new railway cuttings of the Midland branch Railway east and west between Bourn and Saxby, and those of the Manchester, Sheffield, and Lincolnshire Railway north and south between Catesby and Quainton Road, near Aylesbury, have furnished good examples of this variation.

If the weathered soil and subsoil were frozen into the sedentary ice, the disturbance of the underlying rocks, of which many instances are cited, might be produced during the movement and shearing of these basal layers. The *débris* thus removed might rise by overthrusts into higher horizons in the ice, and be

[1] *Geol. Mag.* Dec. 4, iv. p. 485.

then carried forward and widely distributed and commingled with local detritus during alternate recessions and re-advances of the ice-margin, the boulder-clay being deposited, to a large extent, by the melting of the ice, as indicated many years ago by J. G. Goodchild in his account of ice-work in Edenside.

The degrading action of the ice has differed widely in different localities. It is where this action has been most marked, as around the Fenland border, that the large transported masses of Secondary strata have been most frequently observed. Among examples of such masses are the disturbed sheets of chalk of the Norfolk Coast and Trowse, the huge mass at Roslyn Hole, Ely, and that at Catworth described by Mr. A. C. G. Cameron. Other well-known examples are the masses of Lincolnshire Limestone at Great Ponton, and the mass of Marlstone 200 yards across at Beacon Hill, described by Professor Judd; while recently Mr. C. Fox Strangways has observed 'a mass of Lincolnshire Oolite at least 300 yards long and 100 yards broad,' to the north-west of Melton Mowbray. All these occur in connection with the Chalky Boulder-clay.

The author then draws attention to the singular absence of Jurassic outliers along the western margin of the great Lincolnshire 'Cliff,' and he suggests that these huge cakes and boulders were, in some cases, dislodged from outliers which had become frozen to the base of the ice-sheet and were then shifted to higher levels along planes produced in the ice by its movement over an irregular surface. The abundant chalky detritus was no doubt carried along minor planes of movement in the ice, the chalk lumps being scored by fractured flint, and the material being transported far and wide at higher levels in the ice than the bulk of the more local material. In certain instances the soil frozen to the base of the ice-sheet was little, if at all, moved, being overridden by subsequent ice-movements.

The intercalation of sand and gravel with the Chalky Boulder-clay is, he thinks, best explained as a marginal phenomenon produced at different stages in the advance and retreat of the ice-sheet. The author acknowledges his indebtedness to Messrs. Chamberlin, Crosby, and Upham, whose studies have thrown so much light on glacial phenomena.

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6. *Glacial and Interglacial Deposits at Toronto.* *By* A. P. Coleman, *Ph.D., Toronto University.*

The ravines of the river Don at Toronto and the lake cliffs of Scarborough Heights, a few miles to the east, provide exceedingly interesting sections of the drift, from 100 to 350 feet in thickness, displaying three or more sheets of till and a varying number of interglacial beds.

The most important section, at Taylor's brickyard in the Don Valley, shows a lowest till overlying Cambro-Silurian shale of Hudson River age. Upon this rest 18 feet of sand and clay, containing many unios and other shells, as well as leaves and pieces of wood. Some of the unios do not now live in Canadian waters, but are found in the Mississippi; and several species of trees now belonging to the States to the south occur with them, indicating a climate decidedly warmer than the present. Above this come stratified clay and sand, with a caribou horn and remains of insects and plants belonging to a colder climate than the present. This set of clays and sands is best shown at Scarborough, where the series rises 148 feet above Lake Ontario, and contains many species of extinct beetles, as well as shell-fish, mosses, and wood of hardy trees.

A complicated middle till overlies these beds, which were deeply eroded before the advance of the ice. Another less important fossil-bearing interglacial bed occurs above the middle till at elevations up to 240 feet above the lake, and is followed by a third till.

Great changes in the level of the water occurred in connection with these climatic changes, the lake being much lower than at present, before the first glacial advance and after the first interglacial time.

During the deposition of the middle till, and also while the last sheet of till was being deposited, the water stood from 250 to 300 feet above the present level of the lake, which stands 247 feet above the sea.

The retreat of the last ice sheet was followed by the Iroquois episode, leaving a well-marked elevated beach.

The length of time required for the first interglacial period is probably to be estimated at thousands of years; and during this time, at the beginning of which the climate was very warm, the ice sheet of the Laurentide glacier must have completely disappeared.

The correlation of the series of events described with those of the drift of the United States and of Europe is difficult, but probably the chief interglacial period corresponds to Geikie's Neudeckian, or the interval between the Iowan and Wisconsin glacial advances.

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7. *On the Continental Elevation of the Glacial Epoch.*[1] *By* J. W. Spencer, *Ph.D., F.G.S.*

At the last meeting of the British Association, held in Liverpool, Professor Edward Hull presented a paper upon 'Another Possible Cause of the Glacial Epoch,' in which the phenomena of the drowned valleys described by the present writer in the 'Reconstruction of the Antillean Continent'[2] are also accepted by Professor Hull as due to river erosion, thus furnishing yardsticks for measuring the recent elevation of the region.

In that paper the writer described a large number of drowned valleys, often extending from the mouths of the great modern rivers across the submarine plateaus at various depths, reaching to even 12,000 feet or more. The writer now submits evidence showing that similar drowned valleys and amphitheatres are recognisable as far northward as Labrador, beyond which latitude surveys have not been made.

The submarine valleys radiating from the American Continent are no greater than many observable upon the surface of the land, and are particularly comparable to the valleys and *cañons* traversing the plateaus of Mexico and the Western States both in magnitude and in the declivity of the various steps which indicate the pauses in the elevation of the land.

Upon tracing northward the deposits occupying the great valleys, the writer has found that glacial accumulations occur in New Jersey between the Lafayette formation, which is the latest horizon dissected by the great valleys, provisionally regarded as of late Pliocene age, and the Columbia formation, which is mid-Pleistocene. From all these considerations the writer concludes that the eastern portion of North America stood more than two miles above the sea during the earlier Pleistocene epoch.

From the occurrence of certain fossils, and of many *cañons* of recent date incising the borders of the tablelands, it appears that the Mexican plateau was, at least in part, depressed to near sea level during the times of the high elevation of the eastern portion of the continent; and that, with the subsidence of the eastern region, the western side of the continent was elevated from 6,000 to 10,000 feet or more. The separation of the Atlantic and Pacific Oceans is only of recent date.

The soundings in the eastern Atlantic have not always been along the lines which show the best development of the submerged valleys, but the amphitheatres and other valley-features in the subcoastal margin of Europe show some of the phenomena of elevation, after studying their characteristics off the American coast. While a submarine bridge exists between Europe and Greenland, there appears to be no similar connection between Greenland and America. Under these circumstances, the epochs of elevation on the two sides of the Atlantic cannot be shown as simultaneous. On the other hand, it is suggested that the elevation upon the two sides alternated similarly to the terrestrial waves between the eastern region of America and Mexico.

The theory of the Antillean ridge is strongly supported by the distribution of

[1] *Geol. Mag.*, Dec. 4, v. p. 32.

[2] *Bull. Geol. Soc. Amer.*, iv. 1894-95, 103-140.

certain mammals of that time over North and South America, as shown by some of Professor Cope's last work, and by the occurrence of *eliptics* in Guadeloupe.

If the physical phenomena be correctly interpreted, the changes of levels of land and sea, and the dependent variations of currents, &c., seem to be sufficient cause for the Glacial period, as advocated by Lyell and many others, while the writer has only pointed out where changes have occurred.

Since the epoch of great elevation there have been extensive subsidences in America, so that much of the region, where not actually submerged, stood near sea level. The subsequent elevation has been unequal and most pronounced in the mountain regions, as of New England, New York, &c., where tilted beaches, deltas, and terraces occur on all sides of the high mountains in such locations as would require the base levels of erosion to be reduced to near sea level, while the subsequent rise of the land has lifted them to a height of at least 2,700 feet.

Between the phenomena of great elevation and depression there are many others not yet assigned to their proper places, which possibly accounts for various explanations of the surface features.

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8. *The Champlain Submergence and Uplift, and their Relations to the Great Lakes and Niagara Falls. By* FRANK BURSLEY TAYLOR, *of Fort Wayne, Indiana.*

There is much evidence that the disappearance of the Champlain submergence was a recent event in geological time. The skeletons of whales and seals found within the submerged area are not petrefactions, but bones; its marine shells are fresh in appearance. Many of the species found live now in the Gulf of the St. Lawrence. The river channels traversing the old sea bottom betray their youth by many signs. Its soil shows less oxidation than that of the adjoining unsubmerged drift area.

A remarkable abandoned beach surrounds a large portion of the upper Great Lakes. It leads to a low col at the east end of Lake Nipissing, and is hence called the Nipissing beach; and the lake which it bounded, and which was nearly coterminous with the present Lakes Superior, Michigan and Huron, is called the Nipissing Great Lake. It lies in a very even plane which diverges from the present lake level at the rate of nearly seven inches to the mile in a direction about N 27° E. Its maximum elevation is 110 to 115 feet above Lake Superior, and this at Peninsular Harbour; at North Bay it is about 120 feet above Georgian Bay. It meets the present surface of Lake Huron at points nearly opposite the mouth of Saginaw Bay; of Lake Michigan near Traverse and Green Bays, and of Lake Superior not far east from Duluth. Its plane projected would pass about 25 feet under the present lake level at Duluth, 40 feet at Port Huron, and 100 feet at Chicago.

The land exposed between the Nipissing beach and the present water margin is in some places a number of miles in width. It exhibits the same evidences of newness as those found in the uplifted area of the Champlain submergence. Shells found in it are in a similar state of preservation. River channels which cross it are manifestly in the early stages of erosive work. Notable among these is the Nipigon. The inference is strong that the Nipissing Great Lake period was contemporaneous with the Champlain submergence, and that during that time the upper Great Lakes had their outlet by way of the Nipissing pass and Ottawa river.

If this is true there remained only the discharge of Lake Erie to occupy the Niagara. This is at present about one-ninth of the total volume of the river. As the work of this feeble stream we can account for the narrow and shallow gorge of the Whirlpool rapids.

The Champlain Uplift simultaneously uncovered the floor of the Champlain sea, raised the Nipissing beach at the north-east and submerged it at the south-west, closed the Nipissing outlet and opened that at Port Huron, turned the entire discharge of the Great Lakes into the Niagara river, and inaugurated the

cutting of its upper great gorge. Taking the ascertained rate of recession of the Horseshoe fall as the principal datum, the time occupied in that work may have been from 5,000 to 10,000 years, which thus becomes the measure of the time which has elapsed since the emergence of the Champlain area. The measure of the duration of the Champlain submergence is the time occupied in the cutting of the gorge of the Whirlpool rapids. No data exist for its statement in years that would be more than a guess. Such merely conjectural estimate as can be based on the action, or inaction, rather, of the American fall would lead to figures not less than twenty or twenty-five thousand years.

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9. *Remarks introductory to the Excursion to Niagara Falls and Gorge.* *By* G. K. GILBERT.

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10. *Drift Phenomena of Puget Sound and their Interpretation.* *By* BAYLEY WILLIS.

The area from which the facts for this discussion were collected is the Tacoma quadrangle of the United States topographical survey, comprising the district east and south of Seattle and Tacoma. The major topographic features are the channels of the Sound and the strictly homologous valleys now filled with alluvium. These divide, and in some instances surround, plateau-like elevations composed of stratified and unstratified drift that rise about 500 feet above the sea. On the slopes of the adjacent foot hills of the Cascade Range drift deposits occur up to and beyond 1,700 feet above the sea. Various features of the Glacial-derived topography have been traced out in detail, including characteristic till surfaces, morainic zones, kames, and overwash plains. The distribution of these features indicates that at least the latest Glacial advance was along the valleys and channels of the Sound, and that glaciers rose above and overflowed the margins of the plateaus. The materials of the drift are to a large extent granite, and bear evidence of prolonged water transportation. A distinct variety of till, containing numerous erratics of Tertiary volcanics, was found in localities to which it was probably brought from the local centre of glaciation, Mount Rainier. The relation of these local Glacial deposits to the general drift indicates that the prevailing drift phenomena were due to glaciers which penetrated from the north as far south as the foot hills of Mount Rainier, 30 miles south-east of Tacoma.

The detailed examination of the various features of the drift suggests the hypothesis that the channels of the Sound are the hollows remaining after repeated Glacial occupation of a wide valley formerly diversified by the valleys and ridges of pre-Glacial topography. In the course of repeated Glacial advance and retreat the earlier divides were built upon and transformed into plateau-like eminences of Glacial drift, whereas the occupation of the valleys by Glacial ice, particularly in the stagnant stages of retreat, prevented their being permanently filled; with the final retreat of the ice the molds of glaciers remained as the channels of the Sound. This hypothesis is to be contrasted with that of erosion, due to repeated uplift and subsidence.

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11. *The Southern Lobe of the Laurentian Ice Sheet.*[1] *By* Professor C. H. HITCHCOCK.

The ice-sheet of eastern North America had its gathering grounds in the Laurentian highlands, east of Hudson's Bay. Glaciers flowed from it in all directions. Perhaps the most conspicuous discharge was to the south through

[1] For a fuller account of this lobe see *American Geologist*, July 1897, vol. xx., 'The Eastern Lobe of the Ice-sheet.'

the Champlain and Hudson valleys to a point eighty miles out to sea. The study of the striæ shows a series directed southerly through the lowest line of this depression, nowhere much elevated above the sea-level.

On the west the striæ point S.W., and stones have been transported in the same direction. Thus fragments of Potsdam sandstone are strewed over the Adirondack mountains even to their very summits, as proved in 1896 by the writer. All through middle New York and into Pennsylvania, boulders of the Adirondack granites may be seen.

On the east of the central line the striæ point S.E. on the summits of all the Green and White mountains, and boulders from the N.W. have everywhere been carried up to and beyond these summits. Laurentian boulders are found in northern Vermont and New Hampshire, and, in one place at least, over the height of land into Maine.

On examining this area it seems to be a broad lobe, with striæ diverging from the central line, much like the barbs of a feather from the central shaft.

Studies of the Erie, Michigan, and Superior lobes show a similar arrangement of striæ, but the lobes themselves are more acuminate.

This southern lobe is remarkable for its movement from a plain near the sea-level over the highest mountains in New England and New York, 6,000 and 5,000 feet.

The terminal moraines of this great glacial lobe correspond to the two sets of striæ, being rudely at right angles to the direction of the movement in both cases. Those of central New York run meridionally, and then follow down the west side of the Hudson valley. Those in New England are parallel to the margin in the outer portions, and those in N. H. and Vt. run more nearly N.E. and S.W.

As portrayed on the map, the line of junction between this southern lobe and the one coming from Lake Ontario is near Salamanca, N.Y. An angle is made there, which is the most northern part of the unglaciated country outside of the limits traversed by the ice known in the United States.

The moraines of the Ontario lobe are arranged in parallel looped lines, and those in the immediate vicinity of Toronto belong to this series.

If this great lobe had its origin in the Laurentian hills, it is difficult to understand how the ice can have been accumulated at a lower level sufficiently abundantly to move over a higher level, probably three thousand feet. It is easy to see how the Ontario lobe could have made its way, as the greater altitude of the rim of the basin in Ohio is comparatively slight.

The fact that the area of the southern lobe is greater than that of any other, reminds one of the map of the Great Baltic glacier given us by Professor James Geikie.

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12. *On the Origin of Drumlins.*

By N. S. Shaler, *Professor of Geology in Harvard University.*

History of previous studies of drumlins—The question of their origin still undetermined—Method of inquiry—Geographic distribution of phenomena in relation to ice-sheets—Distribution of phenomena by series of forms—Importance of studying drumloidal forms occurring in bed-rock and in morainal hills—Relation of drumlins to moraines—Evidence that drumlins are due to locally intense deposition of detritus—Evidence that they have been subjected in most, if not all, cases to glacial erosion—Analysis of the conditions of local deposition—Reasons for believing that pressure-melting occurring at the base of a glacier induces the formation of drumlins—Relation of drumlins to moraines formed upon previously existing ridges—Phenomena of disappearance of drumlins towards the margin of the ice-sheet—Probable history of drumlin growth as shown by an analysis of the phenomena—Revision of the evidence in relation to the theory.

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13. *The pre-Glacial Decay of Rocks in Eastern Canada. By* ROBERT CHALMERS, *F.G.S.A., of the Geological Survey of Canada.*

Although the question of the subaërial decay of rocks has been before geologists for many years, it does not appear to have received much attention in glaciated countries. One reason of this may be the prominence given to the action of Pleistocene ice in the production of the superficial deposits, the origin of the boulder clay, moraines, kames, &c., being apparently quite readily explained by such action, while the sedentary beds beneath, due to rock decay, are often so thin and fragmentary that they seem to have been overlooked. It is, nevertheless, becoming more and more evident in the detailed study of the superficial deposits that the materials of rock decay, from which all others have been derived, form a very important constituent of the series.

In Eastern Canada a wide field for the study of the products of rock decay exists, in which, so far, but few workers have been found. Sir J. W. Dawson described beds of this kind occurring at Les Eboulements, Quebec, where Utica slates have been changed to a great depth into a sort of clay.[1] Dr. T. Sterry Hunt also observed instances of the similar decomposition of rocks in the vicinity of Montreal, especially at Rigaud Mountain.[2] The writer has been investigating phenomena of this kind since 1884, and has noted beds of decayed rock beneath the boulder clay in New Brunswick, Nova Scotia, Prince Edward Island, and in South-Eastern Quebec, while in the Magdalen Islands the whole of the superficial deposits consist of rock débris, some portions of which are, however, more or less stratified by marine and atmospheric action, no glaciation having taken place there.

In the present paper the question of rock decay during the geological ages which preceded the Tertiary is not considered.

Beds of decomposed rock of variable thickness and more or less modified occur wherever the surface of the rocks has not been abraded by Pleistocene ice, though the evidence of ice action may be present and boulder clay often found overlying them. In South-Eastern Quebec the hilly, broken country along the northern slopes of the Notre Dame range appears to have protected these in some measure from glacial erosion, and hence they occur in thick sheets in certain places, especially in river valleys. The stratified and indigenous pre-Glacial beds met with in the valley of the Chaudière, for example, taken together, are not less than 45 feet thick. In New Brunswick, Nova Scotia, and Prince Edward Island the glaciation has been comparatively light in many districts, and consequently remnants of these materials are found there also, though in a greatly denuded state.

A general section of these beds, as recognised in Eastern Canada, may be given, showing briefly in descending order their character and sequence as noted in different places beneath the boulder clay:—(1) Transported and stratified water-worn gravel with beds of fine sand and clay. (2) Coarse, stratified gravels, usually yellow and oxidised, the materials wholly local. (3) Sedentary rotted rock, passing into solid rock beneath.

Certain portions of the region, as, for example, the eastern extremity of the Gaspé Peninsula, the Magdalen Islands, and some localities in Prince Edward Island, exhibit no abrasion from Pleistocene ice, and the surface, therefore, presents nearly the same appearance as it probably did in the later Tertiary period.

The mineralogical character and consistency of the decayed rock materials are, of course, different upon each geological formation, varying from coarse and angular, upon the older crystallines, to clay, with scaly fragments in districts occupied with slates, and changing into sand and gravel where sandstones prevail.

The products of rock decay as observed beneath the boulder clay are, therefore, of two kinds, indigenous and modified, the latter thickest in the ancient river

[1] Notes on the Post-Pliocene Geology of Canada, *Canadian Naturalist*, vol. vi. 1872.

[2] *American Journal of Science*, vol. xxvi. 1883, pp. 208, 209.

valleys, but often eroded, or entirely swept away by the rivers since the Glacial period in clearing out their channels anew. From the facts at hand it is evident that a mantle of these materials of variable thickness must have occupied the whole region in the later Tertiary period, however, and that denudation from the Pleistocene ice and fluviatile action before and since has left only remnants of it to the present day.

In reference to the precise age of these beds in Eastern Canada, no evidence seems yet to be available. At the western base of the Green Mountains, near Brandon, Vermont, certain beds were discovered many years ago closely resembling those of the Chaudière valley of pre-Glacial date. Lequereux, who studied the vegetable remains which they contained, referred them to the Miocene.[1]

The manner in which the rocks decompose and yield these indigenous products is a question which requires fuller treatment than can be accorded to it in this paper. Decomposition seems, however, to be mainly of two kinds—mechanical and chemical. The most important is doubtless that due to precipitation and to the action of the carbonic acid of the atmosphere. Changes of temperature have also had a very great influence, especially in Eastern Canada, producing contraction and expansion of the rocks, and thus causing numerous joints and fissures into which water and disintegrating agents would find access. Decomposition cannot, however, have proceeded at as rapid a rate in this country as in tropical regions. The mantling of the earth's surface with snow and the freezing up of the superficial deposits for five or six months every year would have a conservative effect, and check the action of the disintegrating forces.

The general aspect of the dry land in Eastern Canada previous to the Glacial period must have been nearly similar to that of the region south of the glaciated zone in North America, though the superficial beds may not, for the reasons stated above, have been as deep. The facts show, however, that rock decay has been in progress for long ages in this country as in other parts of the earth, though apparently with diminished effect.

SATURDAY, AUGUST 21.

The following Papers and Reports were read:—

1. *Note on certain Pre-Cambrian and Cambrian Fossils supposed to be related to Eozoon. By* Sir W. DAWSON, *F.R.S.*

This note relates to fossils referred to in the discussion of the author's paper on Eozoon at the Liverpool meeting last year, and subsequently re-examined by him. It relates to the genera *Cryptozoon* of Hall, *Archæozoon* of Matthew, and *Girvanella* of Nicholson (*Streptochetus* of Seeley). All three are now known in their structures, and have been found in beds ranging from the Lower Cambrian downward. They all seem to be animal forms of low and generalised structure, and probably Protozoa. The specimens referred to can be seen in the Peter Redpath Museum of McGill University, Montreal.

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2. *Note on a Fish Tooth from the Upper Arisaig series of Nova Scotia. By* J. F. WHITEAVES.

The only indication of the existence of vertebrate animals in the Silurian rocks of Canada, that has yet been recorded, is a single specimen of a Pteraspidian fish discovered by Dr. G. F. Matthew in the Nerepis hills of southern New Brunswick in 1886. This specimen, which consists of the rostrum, the lateral cornua, the dorsal and ventral scutes, and some other plates of the anterior armature of the

[1] *Geology of Canada*, 1863, p. 929.

fish, was subsequently described by its discoverer as the type of a new genus, under the name *Diplaspis Acadica*, though Mr. A. Smith Woodward claims that it should be referred to Lankester's genus *Cyathaspis*.

However this may be, in the Museum of the Geological Survey at Ottawa there is a well-preserved fish tooth from the Upper Arisaig series at McDonald's Brook, near Arisaig, N.S., collected by Mr. T. C. Weston in 1869. On the evidence of large numbers of other kinds of fossils, the upper portion of the 'Arisaig series' is still held to be of about the same age as the Lower Helderberg group of the State of New York and the Ludlow group of England, but no Devonian rocks are known to exist at McDonald's Brook.

The tooth itself, which is not quite perfect at either end, is about eleven millimetres in height, by about five in breadth at the base. It is conical, slightly curved, and somewhat compressed, the outline of a transverse section a little below the mid-height being elliptical. It is entirely covered with a thin coat of enamel, which is finely and longitudinally striated.

Judging by its external characters, this specimen seems to be what is usually called a dendrodont tooth, and therefore probably that of a crossopterygian, perhaps allied to *Holoptychius*, though its fore and aft edges are not trenchant. Only one specimen of it has been obtained, so that no thin sections of it have been made, to show its microscopical structure. As it does not seem referable to any known species, it may be convenient to call it provisionally *Dendrodus Arisaigensis*.

If the limestones from which this tooth was collected are, as there is every reason to believe that they are, of Silurian age, a second species can be added to the vertebrate fauna of that system in Canada; but if not, the tooth is still of interest as indicating the possible existence of Devonian rocks at a locality where such rocks have not previously been recognised.

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3. *On some new or hitherto little known Palæozoic Formations in North-Eastern America.* *By* H. M. Ami, *M.A., F.G.S.*

Leaving out of consideration the Cambrian formations of the north-east part of America, which have received careful attention at the hands of Dr. G. F. Matthew and the late Mr. E. Billings, the author discusses the little-known formations or faunas of Ordovician (Cambro-Silurian) age of New Brunswick and Nova Scotia. This is followed by an attempt to subdivide the Silurian formations of the Acadian provinces according to faunas, and by a correlation of these faunas with similar or homotaxial faunas in Northern Europe.

The subdivisions of the Devonian system are then considered, and their faunal relations in the district in question, as well as to areas more to the south and west, in the State of New York and in Ontario.

The paper closes with a synoptical view of the phases which characterised the Carboniferous period of North-Eastern America, a subject of special interest from an economic as well as from a scientific standpoint.

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4. *Some Characteristic Genera of the Cambrian.* *By* G. F. Matthew, *LL.D., D.Sc., F.R.S.C.*

The paper gives in brief the history and use of several generic names and the distribution of certain species to which they have been applied. These genera have an important bearing on the antiquity of the Olenellus Fauna—*Bathyuriscus*, Meek, known as a Middle Cambrian genus in Montana and Nevada, occurs in the Olenellus Fauna of Eastern North America. It is nearly allied to the following genus—*Dolichometopus*, Angelin, of the Upper Paradoxides Beds of Sweden, is found in beds of similar age in Eastern Canada. With it is associated *Dorypyge*, Dames (=Olenoides in part of Walcott), which is a Middle Cambrian genus in Montana, and is found also in the Olenellus Fauna of Eastern North America. *Microdiscus*, a genus of small trilobites, extending in Eastern Canada up to the

Upper Paradoxides Beds, is found in the Olenellus Fauna. *Agnostus* has a peculiar development in the Upper Paradoxides Beds in the appearance at that horizon of the section *Lævigati*; the *Brevifrontes* also abound there. These two sections appear to be present in the fauna with Olenellus.

If we accept the view that there has been a regular development of the faunas through Cambrian time, it is difficult to understand how Olenellus can be at the base of the Cambrian succession and yet found in company with so many genera and sub-genera which are known members of the Middle Cambrian fauna, or that of the Upper Paradoxides Beds. Olenellus has not yet been found below the Paradoxides Beds, and the evidence adduced indicates that it extended *above* rather than below this part of the Cambrian system.

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5. *Report on the Fossil Phyllopoda of the Palæozoic Rocks.*
See Reports, p. 343.

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6. *Report on the Secondary Fossils of Moreseat, Aberdeenshire.*
See Reports, p. 333.

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7. *Influence d'un éboulement sur le Régime d'une rivière.*
Par Mgr. J.-C. K. LAFLAMME, *de l'Université Laval.*

Il s'agit d'un éboulement arrivé sur la rivière Ste-Anne, province de Québec, en avril 1894. Le cours de cette rivière, dans la partie dont il est ici question, se divise en deux sections bien distinctes. Dans chacune la rivière coulait, avant l'éboulis, dans un terrain d'alluvion, où elle avait creusé de longs et nombreux méandres. La section d'amont était peu profonde, mais l'autre, placée près de l'embouchure dans le St-Laurent, était très profonde et à courant très faible. Entre ces deux parties, la rivière traverse une formation calcaire (Trenton), dans laquelle elle a creusé, en certains endroits, une gorge très profonde qui existe encore, mais même là où la gorge n'existe pas, le courant est très rapide.

Un éboulis de plusieurs millions de pieds cubes s'est produit tout à coup dans la section supérieure. L'ancien lit de la rivière a complètement disparu. Elle coule maintenant sur de nouveaux bancs d'argile mis à nu, dans lesquels elle se creuse un chemin. La masse de terre de l'éboulement a été transportée à 10 milles de distance près de l'embouchure, comblant ainsi en partie le chenal profond qui existait là auparavant, augmentant par conséquent la vitesse du courant et provoquant en cet endroit des éboulements riverains, lesquels se continuent encore et ont déjà emporté des surfaces considérables de terres cultivées. On a dû faire des travaux très dispendieux pour sauver le pont du Pacifique, qui était menacé par cette altération du régime de la partie inférieure de la rivière, et le dernier mot n'est pas encore dit. Cette rivière va mettre des années avant de retrouver sa tranquillité primitive.

Cet éboulement est, sans contredit, le plus considérable qui se soit produit de mémoire d'homme dans la province de Québec, et peut-être que l'exposé des principales causes qui l'ont amené et des effets qui l'ont suivi ne sera pas sans intérêt pour la section géologique de l'Association Britannique pour l'avancement des sciences.

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8. *Report of the Coast Erosion Committee of the East Kent and Dover Natural History Societies. By* Captain G. McDAKIN.

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9. *Report of the Fauna of Caves near Singapore.* See Reports, p. 342.

MONDAY, AUGUST 23.

The following Reports and Papers were read:—

1. *Report on the Erratic Blocks of the British Isles.*
See Reports, p. 349.

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2. *On the Relations and Structure of certain Granites and associated Arkoses on Lake Temiscaming, Canada. By* A. E. Barlow, *M.A., and* W. F. Ferrier, *B.A.Sc., Geological Survey of Canada.*

The rocks to which the following facts relate outcrop on both the eastern and western shores of Lake Temiscaming immediately north of the 'Old Fort' Narrows on the upper Ottawa river, the deep channel of which forms the boundary line between the Provinces of Ontario and Quebec.

On the eastern side of the lake the granite forms a strip along the shore half a mile wide, and extending from a point three-quarters of a mile north of The Narrows on which is situated the now abandoned Fort Temiscaming, a fur-trading post belonging to the Hudson Bay Company, to the steamboat wharf near the village of Baie des Pères. It also constitutes the rocky promontory known as Wine Point to the west of Baie des Pères, extending inland in a north-easterly direction for about one mile and a quarter. On the western side of the lake the first outcrop is noticed about half a mile west of 'The Narrows,' continuing along the shore for about four miles as far as Paradis Point, and varying in breadth from half a mile to one mile. The whole area thus underlaid by the granite is approximately about six square miles.

Macroscopically the fresh rock is a rather coarse, though very uniformly even grained aggregate of felspar, quartz, and a dark coloured mica, probably biotite. Felspar is by far the most abundant constituent, and the abundance of red oxide of iron disseminated through all the cracks and fissures of this mineral gives to the rock its beautiful deep flesh-red colour. The quartz is, as usual, allotriomorphic, but a decided tendency is noticed to segregate in more or less rounded areas or individuals which, especially on surfaces worn and polished as a result of glacial action, gives to the rock a porphyritic or pseudo-conglomeratic appearance; a fact first made note of by Sir William Logan in 1844 on his manuscript map of this portion of the Ottawa river.

The microscope shows the rock to be composed essentially of orthoclase, microcline, plagioclase (oligoclase?), quartz, and biotite almost completely altered to chlorite. The microline has evidently been derived from orthoclase as a result of pressure, and all the gradations of this change may be noted, from the 'moire structure' characteristic of the imperfectly or only partially developed mineral, to the fine and typical 'cross-hatched structure' peculiar to this mineral. The felspar shows only incipient alteration to sericite, and scales and flakes of this mineral are developed especially abundantly in the central portion of the individuals, leaving a comparatively fresh periphery almost altogether free from such decomposition products.

The arkose with which this granite is associated and surrounded is a beautiful pale or sea-green quartzite or grit, passing occasionally into a conglomerate, the pebbles of which are chiefly grey and red quartz with occasional intermixed fragments of a hälleflinta-like rock.

Under the microscope the finer-grained matrix appears to be almost wholly composed of pale yellowish-green sericite in the form of minute scales and flakes, although occasional individuals are macroscopically apparent. Most of this sericite has originated from the decomposition *in situ* of felspar originally present, and irregular portions or areas of the unaltered felspar may be occasionally detected.

The line of junction between this granite and arkose shows a gradual and dis-

tinct passage outward or upward from the granite mass. The series of thin sections examined, as well as the hand specimens themselves, show every stage in the process, which has been carefully studied.

In the first place, as a result of dynamic action, the orthoclase is converted into microcline with the incipient development of sericite, which gradually increases in those specimens where the greatest perfection of the 'cross-hatched' microcline structure is reached. In these the individuals of quartz and felspar have undergone rather extensive fracturing, but with little or no movement apart of the fragments. This breaking up of the original larger individuals is, as usual, much more apparent in the quartz than in the felspar, and beautiful examples of 'strain-shadows' may frequently be seen in those quartz areas which have not yielded altogether to the pressure. A further stage in the process is reached when the sericitisation of the felspar has proceeded so far as to permit of the 'shoving apart' of the fragments by the various forces which have acted in bringing about the degradation of the whole rock mass. This gradual decomposition of the felspar and movement of the rock constituents can be perfectly traced in the series of thin sections examined until the rock cannot be distinguished from an ordinary arkose, while the arrangement on the large scale, and the more or less parallel alignment of rounded and waterworn quartzose fragments amply testify to the final assortment and rearrangement of the disintegrated material as a result of ordinary sedimentation.

The relations between this granite and arkose are of rather unusual scientific interest, showing, as they do, the pre-Huronian existence of a basement or floor upon which these sediments were laid down, and which in this portion at least has escaped the movements to which the Laurentian gneisses have been subjected. The granite is also somewhat different, both in composition and appearance, from the granites and gneisses classified as Laurentian, and which are so frequently referred to as the Fundamental Gneiss or Basement Complex, although during recent years the assumption implied in these terms has been considerably weakened by the fact that the contact between such rocks and the associated clastics is, wherever examined, one of intrusion. On the other hand, the composition of the Huronian strata furnishes indubitable evidence of a pre-existing basement or floor essentially granitic in composition, while the abundance of red granite pebbles and fragments, which are so pre-eminently abundant in the breccio-conglomerate lying at the base of the Huronian system, are very similar in composition and appearance to the granite described above. This granite is, therefore, regarded by the authors as the only instance at present known in which the material composing the Huronian clastics can be clearly and directly traced, both macroscopically and microscopically, to the original source from which it has been derived.

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3. *Report on the Irish Elk Remains in the Isle of Man.* See Reports, p. 346.

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4. *On some Nickeliferous Magnetites.*[1] *By* WILLET G. MILLER.

An examination has recently been made of the ore from some of the larger deposits of titaniferous magnetite in eastern Ontario. These magnetites have all been found to be nickeliferous, the amount of nickel (and cobalt) present in some being over 0·8 per cent. The non-titaniferous magnetites of the district have so far as examined been found not to contain nickel.

The titanium-nickel holding magnetites are considered to be of igneous origin, while the other magnetites of the district are thought to be of aqueous or mechanical origin.

The fact that iron produced from titaniferous ores is of a very high quality may have some connection with the occurrence of nickel in these ores. The

[1] A short paper on this subject will appear in the next *Annual Report of the Ontario Bureau of Mines*, Toronto.

superior quality of such iron has been thought by some metallurgists to be due to the presence of titanium in it.

Even a very small percentage of nickel in an iron ore would be of value if the nickel could be extracted along with the iron in smelting, as the resulting alloy might be used directly in the production of nickel-steel.

There is reason to believe that magnetites will be found containing a higher percentage of nickel than those already examined, just as some of the Canadian pyrrhotites, which are also considered to be of igneous origin, contain amounts of nickel which make them valuable as ores, while others contain the metal in lesser amounts.

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5. *Differentiation in Igneous Magmas as a result of Progressive Crystallisation.* *By* J. J. H. Teall, *M.A., F.R.S.*

Crystal building in an originally homogeneous igneous magma necessarily produces differentiation into portions of different chemical composition, a fact the importance of which was first impressed upon the author sixteen years ago in studying the andesitic lavas and their associated quartz porphyry dykes in the Cheviot district.

As is well known, Professor Rosenbusch has classified the common constituents of igneous rocks into (1) the ores and accessory constituents (including magnetite, &c.), (2) the ferro-magnesian constituents, (3) the felspathic constituents, (4) free silica, and has maintained that members of group (1) are the first to form in the process of crystallisation, and that while there are irregularities of order between members of group (2) as compared with those of group (3), yet the members of these groups separate out *inter se* in the order of increasing acidity. This order of crystallisations has been emphasised by many writers, though it has also been clearly recognised that the law is not constant in different magmas and under different conditions. The object of the present communication is to call attention to what is at least an important exception to this law.

Among an extensive series of rocks and fossils collected by the Jackson–Harmsworth expedition in Franz Josef Land, recently examined by the author and Mr. E. T. Newton, are many basalts essentially composed of labradorite, augite, and interstitial matter, in which labradorite formed first, then augite, and last of all the interstitial matter either with or without further differentiation. The main interest of these rocks lies in the composition and relations of the interstitial matter. This is occasionally present as a deep brown glass, but more often is represented either by palagonite or by a turbid and more or less doubly refracting substance crowded with skeleton-crystals of magnetite. In many specimens it is only in this form that magnetite occurs, the labradorite and augite being free from inclusions of this mineral. These facts prove that magnetite may belong to a very late stage of consolidation, and that progressive crystallisation may lead to a concentration of iron oxides in the mother liquor.

The palagonite has undoubtedly been formed by the hydration of a deep brown glass. An analysis was made of it with the following results:—

	I.	II.
Silica	35·48	42·88
Titanic acid	nil.	—
Alumina	8·30	10·03
Ferric oxide	12·30	14·87
Ferrous oxide	14·60	17·65
Lime	1·04	1·26
Magnesia	7·10	8·58
Soda	3·92	4·73
Potash	trace	—
Loss on ignition	16·80	—
	99·54	100·00

In the second column the water is neglected and the percentage composition of the remaining substances indicated. The analysis confirms the view that a great concentration of iron oxide has taken place, and suggests the further conclusion that there has been a concentration of magnesia and a reduction of the lime, silica, and alumina, thus agreeing with the results of the microscopic examination.

Several observers are quoted by the author as having established the fact that magnetite is not always one of the earliest minerals to form, and in basalts of the Franz Josef Land type there is clear evidence that a basic magma may consolidate without any separation of this mineral, although the mother-liquor may contain 30 per cent. of iron oxides.

Brögger, Vogt, and others have observed a tendency in certain dykes for the molecular groups, of which the first-formed minerals are built to migrate towards the cooling margins. The cases examined are mostly those of intermediate rocks, in which the basic minerals are the first to form, so that the margins are more basic than the central parts. But it appears probable that cases occur in which the opposite is true. If the magma of the Franz Josef Land basalts had cooled slowly in a fissure, we should expect to find the central portion of the dyke richer in iron oxide than the margin. Professor Lawson has described two basic dykes from the Rainy Lake region where this is actually the case, and a more striking illustration is seen in the Taberg iron-ore mass, described by Sjögren and Törnebohm, where the marginal portion of an eruptive mass about one square kilometre in area is formed of olivine-hyperite containing only small quantities of magnetite and olivine, which passes inward by gradual stages into a magnetite-olivinite without plagioclase.

In conclusion, it is asked whether the metallic iron which occurs as interstitial matter in some of the Greenland basalts may not have been formed by the reduction, by included organic matter, of the iron oxides previously concentrated by progressive crystallisation.

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6. *The Glaciation of North-Central Canada.* By J. B. Tyrrell.

In the region immediately west of Hudson Bay the earliest glaciation, of which any traces were recognised, flowed outwards from a gathering-ground which lay north or north-west of Doobaunt Lake. Subsequently this gathering-ground moved south-eastward, until it centred over the country between Doobaunt and Yath-kyed Lakes. From one or other of these centres the ice seems, to the writer, to have flowed westward and south-westward to within a short distance of the base of the Rocky Mountains; southward, for more than 1,600 miles to the States of Iowa and Illinois; eastward into the basin of Hudson Bay; and northward into the Arctic Ocean.

No evidence was discovered of any great elevation of this central area in Glacial, or immediately pre-Glacial, times, and, in the absence of such evidence, it would seem not improbable that the land then stood at about the same height above the sea as it stands at present. In this case the moisture giving rise to the immense precipitation of snow would have been derived from the adjacent waters of Hudson Bay and the Arctic Ocean.

The name Keewatin glacier has been applied to this central continental ice-sheet. In general character it appears to have been somewhat similar to the great glacier of North-Western Europe, with a centre lying near the sea-coast, a steep and short slope seaward, and a very much longer and more gentle slope towards the interior of the continent. But there was this difference between the two, that the centre of the latter was over a high rocky country, from which the ice naturally flowed outwards towards the surrounding lower country; while the centre of the former was over what is now, and was probably also then, a low-lying plain, on which the snow accumulated to such depths as to cause it to flow over country very considerably higher.

After the Keewatin glacier had reached its full extent, it began gradually to decrease in size. As it disappeared from the Northern States, and the North-West Territories of Canada, it left a series of moraines, many of which can be readily traced across the unwooded country, as ridges of rounded stony hills. While

retiring down gradually descending slopes, many temporary extra-Glacial lakes were formed in front of it, and were drained one after another as it retired to still lower country. Before it had withdrawn from the Winnipeg basin, it was joined by an advancing glacier from the east, and in front of the two, Lake Agassiz, one of the largest of the extra-Glacial lakes, was formed.

In its final stages the general gathering-ground of the Keewatin glacier seems to have moved still farther eastward, or nearer to the coast of Hudson Bay, and to have broken into several separate centres, one of which lay over the country south-east of Yath-kyed Lake, while another was probably located north of the head of Chesterfield Inlet.

After the retirement of the Keewatin glacier the land in the vicinity of Hudson Bay stood from 500 to 600 feet below its present level, and gradually rose to its present height.

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7. *The Geological Horizons of some Nova Scotia Minerals.* *By* E. GILPIN, Jr., *LL.D., F.R.S.C.*

The principal geological horizons of Nova Scotia are the typically developed divisions of the Carboniferous, followed by interrupted representations of the succeeding divisions down to measures referred by the Geological Survey to the Laurentian.

The Carboniferous affords copper, coal, iron, manganese, barytes, galena, gypsum, grindstone and building stone. The Devonian and Silurian are noted for beds of magnetite and hematite, principally in the Oriskany and Clinton horizons respectively.

The Cambro-Silurian (Longmynd) in one section contains extensive deposits of auriferous quartz worked to some extent.

The Laurentian exposed in Cape Breton has as yet received little attention from a mineralogical point, but is known to contain gold, copper, iron ore, mica, graphite, marble, &c.

TUESDAY, AUGUST 24.

The following Papers and Reports were read:—

1. *On the Possible Identity of* Bennettites, Williamsonia, *and* Zamites gigas. *By* A. C. SEWARD, *M.A., F.G.S., Cambridge.*

The author brings forward evidence in support of the organic connection between *Williamsonia* and the Cycadean fronds known as *Zamites gigas*, L. and H., and in favour of the close relationship, if not identity, of Carruthers' genera *Bennettites* and *Williamsonia.*

In the earliest descriptions of the Jurassic inflorescence known as *Williamsonia* Williamson and other authors regarded the genus as the fructification of the plant which bore the leaves known as *Zamites gigas.* In 1875 Saporta expressed himself strongly against the generally accepted view as to the union of *Williamsonia* and *Zamites.* A recent examination of a series of specimens in the Paris Natural History Museum and elsewhere has convinced the author that *Williamsonia* and *Zamites gigas* are parts of the same plant.

Evidence has been previously brought forward of the practical identity of *Williamsonia* and *Bennettites.* More recently acquired information leads to the conclusion that we are now familiar, not only with the nature of the Bennettitian type of inflorescence, but also with the character of the fronds which were, in some instances, associated with this Jurassic fructification.

In view of the facts before us, it is advisable that the generic name *Williamsonia* should be substituted for the provisional and comprehensive term *Zamites* as the more suitable generic name of Lindley and Hutton's species *Zamites gigas.*

2. *Glacial Geology of Western New York.*[1]
By HERMAN LEROY FAIRCHILD, *B.Sc.*

The glacial and glacio-lacustrine phenomena of Western New York are remarkable for range and variety as well as for their excellent and typical development. The relation of the stratigraphy, topography and altitude of the area, with the effects of static waters and the retreating ice sheet have produced various interesting features. The retreatal moraines lie in two systems, conforming to the ice bodies in the Erie and the Ontario basins. Drumlins are displayed in profusion and of great variety. They are mostly of elongated form, and support the theory of their origin as constructional forms of the ground moraine. Eskers are few, but of typical character, while kames are well developed, some of the kame areas being of great extent and mass.

The pre-Laurentian glacial waters have left an interesting series of well-developed shore lines. These belong to the stages known as Lake Warren and Lake Iroquois and the intermediate falling waters. A differential post-glacial uplift of the region has produced deformation of the shore lines. The remarkable series of parallel valleys holding the several lakes known collectively as the 'Finger' lakes produced a lobing of the retreating ice front, a localising of the moraines, and other significant modifications of the several phenomena.

The paper was especially intended to give the non-American glacialists a brief general view of the various phenomena of the interesting region. The topics, briefly treated, are as follows:—Physical features, ice invasion, glacial deposits, glacio-aqueous deposits, glacial lakes, morainal lakes, channels of glacial drainage, post-glacial stream erosion.

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3. *Second Report on Seismological Investigation.* See Reports, p. 129.

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4. *Earth Strains and Structure.* *By* O. H. HOWARTH.

If we consider the case of any small suspended body subjected to external forces and maintained in its position and motion by the resultant of those forces as we can observe them, it is safe to draw at least parallel conclusions in the case of the earth as to similar effects on an extended scale. It cannot follow that because, in the case of a planetary body revolving in its orbit, we have to regard those forces as enormously greater in degree, and their action as extended over enormously greater periods of time, we must therefore attribute their results to a class of mechanical principles of which we have no cognisance. And amongst the causes whose operation we find recorded in the structure of our earth, there seems obvious reason to assume that the main feature, and by far the most potent, is the constant variation in the balance of external strains to which such a body is subjected. If, as has been admitted by several authorities, these forces bear any part at all in the operations of planet-moulding, surely it follows that it must be immeasurably the greatest. That they operate often silently and in a manner only observable to us by indirect means, is a necessary consequence of our limited powers of perception.

Yet it is surprising to note how large a number of visible effects—seismic, volcanic and structural—seem to be clearly accounted for if we apply on the greater scale of creation those conceptions of dynamic action which we derive from the smaller. It is because these vast developments of force are continually balancing and counteracting each other, and hence create no general cataclysm, that the continuity of their action may escape our observation. But if we realise proportionately the tremendous pressures and the no less tremendous relaxations of pressure under which this ceaseless 'kneading' action proceeds, we must see that the parallel results obtained in a small-scale experiment, however inexact the imitation may be in detail, offer a comparison by no means so

[1] Published *in extenso* in the *Geological Magazine*, 1897, Dec. 4, iv. p. 529.

imaginary as may be thought at first sight. Such forces, exerted under like conditions upon the mass of the earth, ever struggling, as it were, for supremacy, and meeting with all the varying resistances due to widely differing qualities of material, are necessarily sources of an enormous generation of heat wherever a readjustment of that material, even to the slightest extent, ensues. If we conceive such a movement of compressed matter upon itself at a depth of, say, two or three miles within the substance of the earth, a development of heat must occur which, on the release of the strain, will result in the fusion of those particles around large areas of disturbance.

Amongst the many indications of such actions, instances can be quoted where the maxima and minima of chronic volcanic eruption are demonstrably concurrent with those of the tidal strain. In the same manner we can trace to this constant variation of strains many of the more permanent evidences in geological structure, such as the formation of fissure veins and the lamination of igneous rocks—a process wholly distinct from that of sedimentary strata deposited by the action of fluctuating currents of water. The columnar structure of basaltic rocks caused by a gradual release from compressive strain acting equally in all directions may also be illustrated by a small scale experiment.

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5. *Palæozoic Geography of the Eastern States.* *By* E. W. Claypole, *B.A., D.Sc., London.*

An attempt to sketch in outline the general course of the geographical and hydrographical changes which marked the mid-Palæozoic eras in the eastern part of the United States. The subdivision of the Silurian and Devonian eras is carried as far as attainable data allow, and the extinct geography shown by a series of lantern-slides.

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6. *On the Structure and Origin of certain Rocks of the Laurentian System.* *By* Frank D. Adams, *Ph.D., F.R.S.C., McGill University, Montreal.*

The paper presents the results of recent and somewhat extended studies of several areas of the Laurentian of Canada, and deals more particularly with the origin of certain members of this system as indicated by their structure or composition. While it is impossible in the present state of our knowledge to arrive at any definite conclusions concerning the origin of many, or perhaps even of the majority, of the rocks composing the Laurentian, the origin of certain members of the system can be determined. Some of these, although now possessing a more or less distinct and even highly pronounced foliation or stratiform appearance, can be proved to be igneous or intrusive rocks, while it can be shown that others are of aqueous origin.

To the former class belong the anorthosites and many of the orthoclase gneisses. These rocks, although frequently distinctly foliated, can in many places be traced into perfectly massive varieties, and form great intrusions, interrupting and cutting off the older members of the system. The foliation and stratiform appearance which led the older geologists to class them as altered sediments is due to movements induced by pressure, and they show protoclastic or cataclastic structure in great perfection.

To the aqueous rocks, on the other hand, belong the crystalline limestones and certain gneisses usually associated with them. These rocks not only differ in structure from those above referred to, but have a chemical composition not possessed by any igneous rock. The cataclastic structures are very subordinate, and the rocks are characterised by a very extensive recrystallisation, accompanied by the development of new minerals.

It may therefore be said, without going beyond that which the facts warrant, that there are in the Laurentian at least two distinct sets of foliated rocks. One of these, comprising the limestones, some quartzites, and certain garnetiferous or sillimanite gneisses, represents, in all probability, highly altered and extremely

ancient sediments. The other set, intimately associated with these, is of igneous origin, and comprises numerous and very extensive intrusions, both acid and basic in character, which were probably injected at widely separated times. Those masses which were first intruded, and have been subjected to all the subsequent squeezing and metamorphism, are now represented by well-defined and apparently interstratified augen-gneisses and granulites; others, intruded at later periods, though showing the effects of pressure, retain more or less of their massive character; while still others, which have been injected since all movements ceased, are recognised by all as undoubted igneous intrusions.

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7. *Report on Photographs of Geological Interest.* See Reports, p. 298.

WEDNESDAY, AUGUST 25.

1. Joint discussion with Section H. on 'The First Traces of Man in America.'

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2. *Exhibition of the Ferrier Collection of Minerals in the Biological Museum.*

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3. *Exhibition of the Collection of Canadian Fossils in the Museum of the School of Practical Science.*

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4. *Exhibition of a Collection of Devonian Fossils from Western Ontario in the Section Room. By* Dr. S. Woolverton, *London, Ontario.*

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5. *Exhibition of a Collection of British Geological Photographs in the Section Room.*

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION—Professor L. C. MIALL, F.R.S.

THURSDAY, AUGUST 19.

The President delivered the following Address:—

IT has long been my conviction that we study animals too much as dead things. We name them, arrange them according to our notions of their likeness or unlikeness, and record their distribution. Then perhaps we are satisfied, forgetting that we could do as much with minerals or remarkable boulders. Of late years we have attempted something more; we now teach every student of Zoology to dissect animals and to attend to their development. This is, I believe, a solid and lasting improvement; we owe it largely to Huxley, though it is but a revival of the method of Döllinger, who may be judged by the eminence of his pupils and by the direct testimony of Baer to have been one of the very greatest of biological teachers. But the animals set before the young zoologist are all dead; it is much if they are not pickled as well. When he studies their development, he works chiefly or altogether upon continuous sections, embryos mounted in balsam, and wax models. He is rarely encouraged to observe live tadpoles or third-day chicks with beating hearts. As for what Gilbert White calls the *life and conversation of animals*, how they defend themselves, feed, and make love, this is commonly passed over as a matter of curious but not very important information; it is not reputed scientific, or at least not eminently scientific.

Why do we study animals at all? Some of us merely want to gain practical skill before attempting to master the structure of the human body; others hope to qualify themselves to answer the questions of geologists and farmers; a very few wish to satisfy their natural curiosity about the creatures which they find in the wood, the field, or the sea. But surely our chief reason for studying animals ought to be that we would know more of life, of the modes of growth of individuals and races, of the causes of decay and extinction, of the adaptation of living organisms to their surroundings. Some of us even aspire to know in outline the course of life upon the earth, and to learn, or, failing that, to conjecture, how life originated. Our own life is the thing of all others which interests us most deeply, but everything interests us which throws even a faint and reflected light upon human life. Perhaps the professor of Zoology is prudent in keeping so close as he does to the facts of structure, and in shunning the very attempt to interpret, but while he wins safety he loses his hold upon our attention. Morphology is very well; it may be exact; it may prevent or expose serious errors. But Morphology is not an end in itself. Like the systems of Zoology, or the records of distribution, it draws whatever interest it possesses from that life which creates organs and adaptations. To know more of life is an aim as nearly ultimate and self-explanatory as any purpose that man can entertain.

Can the study of life be made truly scientific? Is it not too vast, too inaccessible to human faculties? If we venture into this alluring field of inquiry, shall

we gain results of permanent value, or shall we bring back nothing better than unverified speculations and curious but unrelated facts?

The scientific career of Charles Darwin is, I think, a sufficient answer to such doubts. I do not lay it down as an article of the scientific faith that Darwin's theories are to be taken as true; we shall refute any or all of them as soon as we know how; but it is a great thing that he raised so many questions which were well worth raising. He set all scientific minds fermenting, and not only Zoology and Botany, but Palæontology, History, and even Philology bear some mark of his activity. Whether his main conclusions are in the end received, modified, or rejected, the effect of his work cannot be undone. Darwin was a bit of a sportsman and a good deal of a geologist; he was a fair anatomist and a working systematist; he keenly appreciated the value of exact knowledge of distribution. I hardly know of any aspect of natural history, except synonymy, of which he spoke with contempt. But he chiefly studied animals and plants as living beings. They were to him not so much objects to be stuck through with pins, or pickled, or dried, or labelled, as things to be watched in action. He studied their difficulties, and recorded their little triumphs of adaptation with an admiring smile. We owe as many discoveries to his sympathy with living nature as to his exactness or his candour, though these too were illustrious. It is not good to idolise even our greatest men, but we should try to profit by their example. I think that a young student, anxious to be useful but doubtful of his powers, may feel sure that he is not wasting his time if he is collecting or verifying facts which would have helped Darwin.

Zoologists may justify their favourite studies on the ground that to know the structure and activities of a variety of animals enlarges our sense of the possibilities of life. Surely it must be good for the student of Human Physiology, to take one specialist as an example of the rest, that he should know of many ways in which the same functions can be discharged Let him learn that there are animals (star-fishes) whose nervous system lies on the outside of the body, and that in other animals it is generally to be found there during some stage of development; that there are animals whose circulation reverses its direction at frequent intervals either throughout life (Tunicata) or at a particular crisis (insects at the time of pupation); that there are animals with eyes on the back (Oncidium, Scorpion), on the shell (some Chitonidæ), on limbs or limb-like appendages, in the brain-cavity, or on the edge of a protective fold of skin; that there are not only eyes of many kinds with lenses, but eyes on the principle of the pin-hole camera without lens at all (Nautilus) and of every lower grade down to mere pigment-spots; that auditory organs may be borne upon the legs (insects) or the tail (Mysis); that they may be deeply sunk in the body, and yet have no inlet for the vibrations of the sonorous medium (many aquatic animals). It is well that he should know of animals with two tails (Cercaria of Gasterostomum) or with two bodies permanently united (Diplozoon); of animals developed within a larva which lives for a considerable time after the adult has detached itself (some star-fishes and Nemertines); of animals which lay two (Daphnia) or three kinds of eggs (Rotifera); of eggs which regularly produce two (Lumbricus trapezoides) or even eight embryos apiece (Praopus[1]); of males which live parasitically upon the female (Cirripedes), or even undergo their transformations, as many as eighteen at a time in her gullet (Bonellia); of male animals which are mere bags of sperm-cells (some Rotifera, some Ixodes, parasitic Copepods) and of female animals which are mere bags of eggs (Sacculina, Entoconcha). The more the naturalist knows of such strange deviations from the familiar course of things, the better will he be prepared to reason about what he sees, and the safer will he be against the perversions of hasty conjecture.

If a wide knowledge of animals is a gain to Physiology and every other branch of Biology, what opportunities are lost by our ignorance of the early stages of so many animals! They are often as unlike to the adult in structure and

[1] Hermann von Jhering, *Sitz. Berl. Akad.*, 1885; *Biol. Centralbl.*, Bd. vi pp. 532–539 (1886).

function as if they belonged to different genera, or even to different families. Zoologists have made the wildest mistakes in classifying larvæ whose subsequent history was at the time unknown. The naturalist who devotes himself to life-histories shares the advantage of the naturalist who explores a new continent. A wealth of new forms is opened out before him. Though Swammerdam, Réaumur, De Geer, Vaughan Thompson, Johannes Müller and a crowd of less famous naturalists have gone before us, so much remains to be done that no zealous inquirer can fail to discover plenty of untouched subjects in any wood, thicket, brook or sea.

Whoever may attempt this kind of work will find many difficulties and many aids. He will of course find abundant exercise for all the anatomy and physiology that he can command. He will need the systems of descriptive Zoology, and will often be glad of the help of professed systematists. The work cannot be well done until it is exactly known what animal is being studied. For want of this knowledge, hardly attainable 150 years ago, Réaumur sometimes tells us curious things which we can neither verify nor correct; at times we really do not know what animal he had before him. The student of life-histories will find a use for physics and chemistry, if he is so lucky as to remember any. Skill in drawing is valuable, perhaps indispensable.

If by chance I should be addressing any young naturalist who thinks of attending to life-histories, I would beg him to study his animals alive and under natural conditions. To pop everything into alcohol and make out the names at home is the method of the collector, but life-histories are not studied in this way. It is often indispensable to isolate an animal, and for this purpose a very small habitation is sometimes to be preferred. The tea-cup aquarium, for instance, is often better than the tank. But we must also watch an animal's behaviour under altogether natural circumstances, and this is one among many reasons for choosing our subject from the animals which are locally common. Let us be slow to enter into controversies. After they have been hotly pursued for some time, it generally turns out that the disputants have been using words in different senses. Discussion is excellent, controversy usually barren. Yet not always; the Darwinian controversy was heated, and nevertheless eminently productive; all turns upon the temper of the men concerned, and the solidity of the question at issue. One more hint to young students. Perhaps no one ever carried through a serious bit of work without in some stage or other longing to drop it. There comes a time when the first impulse is spent, and difficulties appear which escaped notice at first. Then most men lose hope. That is the time to show that we are a little better than most men. I remember as a young man drawing much comfort from the advice of a colleague, now an eminent chemist, to whom I had explained my difficulties and fears. All that he said was: 'Keep at it,' and I found that nothing more was wanted.

I greatly believe in the value of association. It is good that two men should look at every doubtful structure and criticise every interpretation. It is often good that two talents should enter into partnership, such as a talent for description and a talent for drawing. It is often good that an experienced investigator should choose the subject and direct the course of work, and that he should be helped by a junior, who can work, but cannot guide. It seems to me that friendly criticism before publication is often a means of preventing avoidable mistakes. I am sorry that there should be any kind of prejudice against co-operation, or that it should be taken to be a sign of weakness. There are, I believe, very few men who are so strong as not to be the better for help. One difficulty would be removed if known authors were more generous in acknowledging the help of their assistants. They ought not to be slow to admit a real helper to such honour as there may be in joint-authorship.

Among the most important helps to the student of life-histories must be mentioned the zoological stations now maintained by most of the great nations. The parent of all these, the great zoological station at Naples, celebrated its twenty-fifth anniversary last April, so that the whole movement belongs to our own generation. How would Spallanzani and Vaughan Thompson and Johannes

Müller have rejoiced to see such facilities for the close investigation of the animal life of the sea! The English-speaking nations have taken their fair share of the splendid work done at Naples, and it is pleasant to remember that Darwin subscribed to the first fund, while the British Association, the University of Cambridge and the Smithsonian Institution have maintained their own tables at the station.[1] The material support thus given is small when compared with the subsidies of the German Government, and not worth mention beside the heroic sacrifices of the Director, Dr. Anton Dohrn, but as proofs of lively interest in a purely scientific enterprise they have their value. Marine stations have now multiplied to such a point that a bare enumeration of them would be tedious. Fresh-water biological stations are also growing in number. Forel set an excellent example by his investigation of the physical and biological phenomena of the Lake of Geneva. Dr. Anton Fritsch of Prag followed with his movable station. There is a well-equipped station at Plön among the lakes of Holstein, and a small one on the Müggelsee near Berlin. The active station of Illinois is known to me only by the excellent publications which it has begun to issue. France, Switzerland, Sweden and Finland all have their fresh-water biological stations, and I hope that England will not long remain indifferent to so promising a sphere of investigation.

Biological work may answer many useful purposes. It may be helpful to industry and public health. Of late years the entomologist has risen into sudden importance by the vigorous steps taken to discourage injurious insects. I have even known a zoological expert summoned before a court of law in order to say whether or not a sword-fish can sink a ship. I would not on any account run down the practical applications of Biology, but I believe that the first duty of the biologist is to make science, and that science is made by putting and answering questions. We are too easily drawn off from this, which is our main business, by self-imposed occupations, of which we can often say nothing better than that they do no harm except to the man who undertakes them. There are, for example, a good many lists of species which are compiled without any clear scientific object. We have a better prospect of working to good purpose when we try to answer definite questions. I propose to spend what time remains in putting and answering as well as I can a few of the questions which occur to any naturalist who occupies himself with life-histories. Even a partial answer—even a mistaken answer is better than the blank indifference of the collector, who records and records, but never thinks about his facts.

The first question that I will put is this:—Why do some animals undergo transformation while others do not? It has long been noticed[2] that as a rule fresh-water and terrestrial animals do not go through transformation, while their marine allies do. Let us take half-a-dozen examples of each:—

Fluviatile or terrestrial. Without transformation.	*Marine. With transformation.*
Crayfish.	Crab.
Earthworm.	Polygordius.
Helix.	Doris, Æolis.
Cyclas.	Oyster.
Hydra.	Most Hydrozoa.
&c.	&c.

We get a glimmer of light upon this characteristic difference when we remark that in fresh-water and terrestrial species the eggs are often larger than in the allied marine forms. A large egg favours *embryonic* as opposed to *larval* development. An embryo which is formed within a large egg may feed long upon the food laid up for it, and continue its development to a late stage before hatching. But if there is little or no yolk in the egg, the embryo will turn out early to shift for itself. It will be born as a larva, provided with provisional organs suited to its small size and weakness. Large eggs are naturally fewer than small ones.

[1] To this list may now be added the University of Oxford.

[2] Darwin, *Origin of Species*, chap. xiii.; Fritz Müller, *Für Darwin*, chap. vii.

Does the size depend on the number, or the number on the size? To answer in a word, I believe that the size generally depends on the number, and that the number is mainly determined by the risks to which the species are exposed. At least so many eggs will in general be produced as can maintain the numbers of the species in spite of losses, and there is some reason to believe that in fresh waters the risks are less than in the shallow seas or at the surface of the ocean.[1] In most parts of the world the fresh waters are of small size, and much cut up. Every river-basin forms a separate territory. Isolation, like every other kind of artificial restriction, discourages competition, and impedes the spread of successful competitors. In the shallow seas or at the surface of the ocean conquering forms have a free course; in lakes and rivers they are soon checked by physical barriers.

A large proportion of animals are armour-clad, and move about with some difficulty when they have attained their full size. The dispersal of the species is therefore in these cases effected by small and active larvæ. Marine animals (whether littoral or pelagic) commonly produce vast numbers of locomotive larvæ, which easily travel to a distance. Floating is easy, and swimming not very difficult. A very slightly built and immature larva can move about by cilia, or take advantage of currents, and a numerous brood may be dispersed far and wide while they are mere hollow sacs, without mouth, nerves or sense-organs. Afterwards they will settle down, and begin to feed. In fresh waters armour is as common, for all that I know, as in the sea, but locomotive larvæ are rare.[2] There is no space for effective migration. Even a heavy-armoured and slow-moving crustacean or pond-snail can cross a river or lake, and to save days or hours is unimportant. In rivers, as Sollas has pointed out, free-swimming larvæ would be subject to a special risk, that of being swept out to sea. This circumstance may have been influential, but the diminished motive for migration is probably more important. At least an occasional transport to a new area is indispensable to most freshwater organisms, and very unexpected modes of dispersal are sometimes employed, not regularly in each generation, but at long intervals, as opportunity offers.

Early migration by land is nearly always out of the question. Walking, and still more flying, are difficult exercises, which call for muscles of complex arrangement and a hard skeleton. A very small animal, turned out to shift for itself on land, would in most cases perish without a struggle. There might be just a chance for it, if it could resist superficial drying, and were small enough to be blown about by the wind (Infusoria, Rotifera, and certain minute Crustacea), or if it were born in a wet pasture, like some parasitic worms.

We can define two policies between which a species can make its choice. It may produce a vast number of eggs, which will then be pretty sure to be small and ill-furnished with yolk. The young will hatch out early, long before their development is complete, and must migrate at once in search of food. They will, especially if the adult is slow-moving or sedentary, be furnished with simple and temporary organs of locomotion, and will generally be utterly unlike the parent. The majority will perish early, but one here and there will survive to carry on the race.

Or the parent may produce a few eggs at a time, stock them well with yolk,

[1] Indications are given by the survival in fresh waters of declining groups, *e.g.*, Ganoid Fishes, which, when dominant, maintained themselves in the sea; and by the not uncommon case of marine animals which enter rivers to spawn. I do not attempt to count among these indications the supposed geological antiquity of fluviatile as compared with marine animals. Some marine genera are extremely ancient (Lingula, Nucula, Trigonia, Nautilus); a perfectly fair comparison is almost impossible; and great persistence does not necessarily imply freedom from risks. In the Mollusca, which afford a good opportunity of testing the effect of habitat upon the number of the eggs, marine species seem to produce more eggs as a rule than fluviatile, and these many more than terrestrial species.

[2] Dreyssensia and Cordylophora are examples of animals which seem to have quite recently become adapted to fresh-water life, and have not yet lost their locomotive larvæ. Many instances could be quoted of marine forms which have become fluviatile. The converse is, I believe, comparatively rare.

and perhaps watch over them, or even hatch them within her own body. The young will in such cases complete their development as embryos, and when hatched, will resemble the parent in everything but size.

Which policy is adopted will largely depend upon the number of the family and the capital at command. There are animals which are like well-to-do people, who provide their children with food, clothes, schooling, and pocket-money. Their fortunate offspring grow at ease, and are not driven to premature exercise of their limbs or wits. Others are like starving families, which send the children, long before their growth is completed, to hawk matches or newspapers in the streets.

In Biology we have no sooner laid down a principle than we begin to think of exceptions. The exceptions may be apparent only; they may, when fully understood, confirm instead of disturbing the general principle. But this rarely happens unless the principle is a sound one. *Exceptio probat regulam*; it is the exception which tests the rule, to give a new application to an old maxim.

Parasites form one group of exceptions to our rule. Whether they pass their free stages in air, water or earth, whether their hosts are marine, fluviatile or terrestrial, they are subject to strange transformations, which may be repeated several times in the same life-history. The change from one host to another is often a crisis of difficulty; many fail to accomplish it; those which succeed do so by means of some highly peculiar organ or instinct, which may be dropped as quickly as it is assumed. The chances of failure often preponderate to such an extent that an enormous number of eggs must be liberated. Even a brief parasitism may produce a visible effect upon the life-history. The young Unio or Anodon attaches itself for a short time to some fish or tadpole. To this temporary parasitism is due, as I suppose, the great number of eggs produced, and a degree of metamorphosis, unusual in a fresh-water mollusk.

The Cephalopoda, which are wholly marine, and the Vertebrates, whatever their habitat, very rarely exhibit anything which can be called transformation. Some few cases of Vertebrate transformation will be discussed later. Cephalopods and Vertebrates are large, strong, quick-witted animals, able to move fast, and quite equal in many cases to the defence of themselves and their families. They often produce few young at a time, and take care of them (there are many examples to the contrary among Cephalopods and Fishes). They are generally able to dispense with armour, which would have indirectly favoured transformation.

Echinoderms, which are all marine, develop with metamorphosis. There is an interesting exception in the Echinoderms with marsupial development, which develop directly, and give an excellent illustration of the effect of parental care.

Insects, which as terrestrial animals should lay a few large eggs, and develop directly, furnish the most familiar and striking of all transformations. I have already discussed this case at greater length than is possible just now.[1] I have pointed out that the less specialised insect-larvæ, *e.g.* those of Orthoptera, make a close approach to some wingless adult insects, such as the Thysanura, as well as to certain Myriopods. Fritz Müller seems to me to be right in saying that the larvæ of non-metamorphic insects come nearer than any winged insect to primitive Tracheates. The transformation of the Bee, Moth, or Blow-fly is transacted after the stage in which the normal Tracheate structure is attained, and I look upon it as a peculiar *adult* transformation, having little in common with the transformations of Echinoderms, Mollusks, or Crustaceans.

In the same way I believe that some Amphibia have acquired an adult transformation. Frogs and toads, having already as tadpoles attained the full development of the more primitive Amphibia, change to lung-breathing, tailless, land-traversing animals, able to wander from the place of their birth, to seek out mates from other families, and to lay eggs in new sites.

Medusæ furnish a third example of adult transformation, which seems to find its explanation in the sedentary habit of the polyp, which probably nearly approaches the primitive adult stage. But here the case is further complicated,

[1] *Nature*, Dec. 19, 1895.

for the polyp still proceeds from a planula, which is eminently adapted for locomotion, though perhaps within a narrower range. We have two migratory stages in the life-history. Each has its own advantages and disadvantages. The planula, from its small size, is less liable to be devoured, or stranded, or dashed to pieces, but it cannot travel far; the medusa may cross wide seas, but it is easily captured and is often cast up upon a beach in countless multitudes.

Adult transformation may be recognised by its occurrence after the normal structure of the group has been acquired, and also by its special motive, which is egg-laying and all that pertains to it; the special motive of larval transformation is dispersal for food.

The reproduction of the common Eel has been a mystery ever since the days of Aristotle, though a small part of the story was made out even in ancient times. It was long ago ascertained that the Eel, which seeks its food in rivers, descends to the sea in autumn or early winter, and that it never spawns, nor even becomes mature in fresh waters. The Eels which descend to the sea never return, but young eels or Elvers come up from the sea in spring, millions at a time. The Elvers have been seen to travel along the bank of a river in a continuous band or eel-rope, which has been known to glide upwards for fifteen days together. It was of course concluded that spawning and early development took place in the sea during the interval between the autumn and spring migration, but no certain information came to hand till 1896. Meanwhile this gap in our knowledge was a perplexity, almost a reproach to zoologists. The partially-known migration of the Eel could not be harmonised with the ordinary rule of migratory fishes. We tried to explain the passage of marine fishes into rivers at spawning time by the supposition (a true supposition, as I think) that the river is less crowded than the shallow seas, and therefore a region in which competition is less severe. The river is to some migratory fishes what the tundras of Siberia are to some migratory birds, places comparatively free from dangerous enemies, and therefore fit for the rearing of the helpless young. But the Eel broke the rule, and cast doubt upon the explanation. The Salmon, Sturgeon and Lamprey feed and grow in the sea, and enter rivers to spawn. The Eel feeds and grows in rivers, but enters the sea to spawn. What possible explanation could meet cases thus diametrically opposite?

This was the state of matters when Grassi undertook to tell us that part of the history of the Eel which is transacted in the sea. When it leaves the river, it makes its way to very deep water, and there undergoes a change. The eyes enlarge, and become circular instead of elliptical; the pectoral fins and the border of the gill-cover turn black; the reproductive organs, only to be discovered by microscopic search before this time, enlarge. The Eels, thus altered in appearance and structure, lay their eggs in water of not less than 250 fathoms' depth. The upper limit of the spawning-ground is nearly three times as far from sea-level as the 100-fathom line which we arbitrarily quote as the point at which the deep sea begins. The eggs, which are large for a fish (2·7 mm. diam.), float but do not rise. The young which issue from them are quite unlike the Eels of our rivers; they are tape-like, transparent, colourless, devoid of red blood and armed with peculiar teeth. A number of different kinds of such fishes had been previously known to the naturalist as Leptocephali. Günther had conjectured that they were abnormal larvæ, incapable of further development. Grassi has, however, succeeded in proving that one of these Leptocephali (L. brevirostris) is simply a larval Eel; others are larvæ of Congers and various Murænoid fishes. He has with infinite pains compared a number of Leptocephali, and co-ordinated their stages, making out some particularly important ones by the direct observation of live specimens.

You will not unnaturally ask how Grassi or anybody else can tell what goes on in the sea at a depth of over 250 fathoms. His inquiries were carried on at Messina, where the local circumstances are very fortunate. Strong currents now and then boil up in the narrow strait, sweeping to the surface eggs, larvæ, and a multitude of other objects which at ordinary seasons lie undisturbed in the tranquil depths. Further information has been got by dredging, and also by opening the body of a sun-fish (Orthagoriscus mola), which at certain times of the year is

taken at the surface, and is always found to contain a number of Leptocephali. When a Leptocephalus has completed its first stage of growth, it ceases to feed, loses bulk, and develops pigment on the surface of the body. At the same time the larval teeth are cast, and the larval skeleton is replaced. Then the fish begins to feed again, comes to the surface, enters the mouth of a river, and, if caught, is immediately recognised as an Elver or young Eel. It is now a year old, and about two inches long.

This history suggests a question. Are the depths of the sea free from severe competition? The darkness, which must be nearly or altogether complete, excludes more than the bare possibility of vegetation. A scanty subsistence for animals is provided by the slowly decomposing remains of surface-life. When the dredge is sunk so low, which does not often happen, it may bring up now and then a peculiar and specially modified inhabitant of the dark and silent abyss. There cannot, we should think, be more than the feeblest competition where living things are so few, and the mode of life so restricted. Going a step further, we might predict that deep-sea animals would lay few eggs at a time, and that these would develop directly—*i.e.* without transformation. The risk of general reasoning about the affairs of living things is so great that we shall hold our conjectures cheap unless they are confirmed by positive evidence. Happily this can be supplied. The voyage of the 'Challenger' has yielded proof that the number of species diminishes with increasing depth, and that below 300 fathoms living things are few indeed.[1] Dr. John Murray gives us the result of careful elaboration of all the facts now accessible, and tells us that the majority of the abyssal species develop directly.[2]

We seem therefore to have some ground for believing that the depths of the sea resemble the fresh waters in being comparatively free from enemies dangerous to larvæ. The Eel finds a safe nursery in the depths, and visits them for the same reason that leads some other fishes to enter rivers. It may be that the depths of the sea are safer than rivers, in something like the same degree and for the same reasons that rivers are safer than shallow seas. But we must be careful not to go too fast. It may turn out that deep recesses in the shallower seas—holes of limited extent in the sea-bottom—enjoy an immunity from dangerous enemies not shared by the great and continuous ocean-floor.[3]

After this short review of the facts I come to the conclusion that the general rule which connects the presence or absence of transformation with habitat is well-founded, but that it is apt to be modified and even reversed by highly special circumstances. The effect of habitat may for instance be overruled by parasitism, parental care, a high degree of organisation, or even by a particular trick in egg-laying. The direct action of the medium is probably of little consequence. Thus the difference between fresh and salt water is chiefly important because it prevents most species from passing suddenly from one to the other. But the abyssal and the fluviatile faunas have much in common, as also have the littoral and the pelagic faunas. Relative density and continuity of population seem to be of vital importance, and it is chiefly these that act upon the life-history.

In Zoology, as in History, Biography, and many other studies, the most interesting part of the work is only to be enjoyed by those who look into the details. To learn merely from text-books is notoriously dull. The text-book has its uses, but, like other digests and abridgments, it can never inspire enthusiasm. It is the same with most lectures. Suppose that the subject is that well-worn topic, the Alternation of Generations. The name recalls to many of us some class-room of our youth, the crudely coloured pictures of unlikely animals which hung on the walls, and the dispirited class, trying to write down from the lecture the irreducible minimum which passes a candidate. The lecturer defines his terms and

[1] *Challenger Reports.* Summary of Scientific Results (1895), pp. 1430–6.

[2] *Nature*, March 25, 1897.

[3] I am aware that other things affect the interests of animals, and indirectly determine their structure, besides danger from living enemies. So complicated a subject can only be discussed in a short space if large omissions are tolerated.

quotes his examples; we have Salpa, and Aurelia, and the Fern, and as many more as time allows. How can he expect to interest anybody in a featureless narrative, which gives no fact with its natural circumstances, but mashes the whole into pemmican? What student goes away with the thought that it would be good and pleasant to add to the heap of known facts? The heap seems needlessly big already. And yet every item in that dull mass was once deeply interesting, moving all naturalists and many who were not naturalists to wonder and delight. The Alternation of Generations worked upon men's minds in its day like Swammerdam's discovery of the butterfly within the caterpillar, or Trembley's discovery of the budding Hydra, which when cut in two made two new animals, or Bonnet's discovery that an Aphis could bring forth living young without having ever met another individual of its own species. All these wonders of nature have now been condensed into glue. But we can at any time rouse in the minds of our students some little of the old interest, if we will only tell the tale as it was told for the first time.

Adalbert Chamisso, who was in his time court-page, soldier, painter, traveller, poet, novelist, and botanist, was the son of a French nobleman. When he was nine years old, he and all the rest of the family were driven out of France by the French Revolution. Chamisso was educated anyhow, and tried many occupations before he settled down to Botany and light literature. In 1815 he embarked with Eschscholtz on the Russian voyage round the world commanded by Kotzebue. The two naturalists (for Chamisso is careful to associate Eschscholtz with himself, and even to give him priority) discovered a highly curious fact concerning the Salpæ, gelatinous Tunicates which swim at the surface of the sea, sometimes in countless numbers. There are two forms in the same species, which differ in anatomical structure, but especially in this, that one is solitary, the other composite, consisting of many animals united into a chain which may be yards long. Chamisso and Eschscholtz ascertained that the solitary form produces the chain-form by internal budding, while the chain-form is made up of hermaphrodite animals which reproduce by fertilised eggs.[1] There is thus, to use Chamisso's own words, 'an alternation of generations. . . . It is as if a caterpillar brought forth a butterfly, and then the butterfly a caterpillar.' Here the phrase *bring forth* is applied to two very different processes, viz. sexual reproduction and budding. Chamisso's phrase, 'alternation of generations,' is not exact. Huxley would substitute *alternation of generation with gemmation,* and if for shortness we use the old term, it must be with this new meaning. Subsequent investigation, besides adding many anatomical details, has confirmed one interesting particular in Chamisso's account, viz. that the embryo of Salpa is nourished by a vascular placenta.[2] The same voyage yielded also the discovery of Appendicularia, a permanent Tunicate tadpole, and the first tadpole found in any Tunicate.

Some ten years after the publication of Chamisso's alternation of generations in Salpa, a second example was found in a common jelly-fish (Aurelia). Not a few Hydrozoa had by this time been named, and shortly characterised. Some were polyps, resembling the Hydra of our ponds, but usually united into permanent colonies; others were medusæ, bell-shaped animals which swim free in the upper waters of the sea. It was already suspected that both polyps and medusæ had a common structural plan, and more than one naturalist had come very near to knowing that medusæ may be the sexual individuals of polyp-colonies.

This was the state of matters when an undergratuate in Theology of the University of Christiania, named Michael Sars, discovered and described two new polyps, to which he gave the names, now familiar to every zoologist, of Scyphistoma and Strobila. In the following year (1830) Sars settled at Kinn, near

[1] Brooks maintains that the solitary Salpa, which is female, produces a chain of males by budding, and lays an egg in each. These eggs are fertilised while the chain is still immature, and develop into females (solitary Salpæ). The truth of this account must be determined by specialists.

[2] Cuvier had previously noted the fact.

Bergen, as parish priest, and betook himself to the lifelong study of the animals of the Norwegian seas. He soon found out that his Scyphistoma was merely an earlier stage of his Strobila. Scyphistoma has a Hydra-like body, less than half an inch long, and drawn out into a great number of immensely long tentacles. It buds laterally like a Hydra, sending out stolons or runners, which bear new polyps, and separate before long, the polyps becoming independent animals. In the midst of the tentacles of the scyphistoma is a prominence which bears the mouth. This grows upwards into a tall column, the strobila, which is supported below by the scyphistoma. When the strobila is well nourished it divides into transverse slices, which at length detach themselves, and swim away.[1] These are the Ephyræ, which had been found in the sea before Sars' time, and were then counted as a particular kind of adult medusæ. They are small, flat discs with eight lobes or arms, all notched at the extremity. A pile of ephyræ is produced by the transverse constriction and division of the strobila in a fashion which reminds us of the rapid production of the animals in a Noah's ark by the slicing of a piece of wood of suitable sectional figure. It was thus ascertained that the scyphistoma, strobila, and ephyra are successive stages of one animal, but for a time no one could say where the scyphistoma came from, nor what the ephyra turned to. At length Sars, aided by the anatomical researches of Ehrenberg and Siebold, was able to clear up the whole story. The ephyra is gradually converted by increase of size and change of form into an Aurelia, a common jelly-fish which swarms during the summer in European seas. The Aurelia is of two sexes, and the eggs of the female give rise to ciliated embryos, which had been seen before Sars' time, but wrongly interpreted as parasites or diminutive males. These ciliated embryos, called planulæ, swim about for a time, and then settle down as polyps (scyphistomata). There is thus a stage in which Aurelia divides without any true reproductive process, and another stage in which it produces fertile eggs. There is alternation of generations in Aurelia as well as in Salpa, and Sars was glad to fortify by a fresh example the observations of Chamisso, on which doubts had been cast.

It was not long before the alternation of generations was recognised in Hydromedusæ also, and then the ordinary Hydrozoan colony was seen to consist of at least two kinds of polyps, one sexual, the other merely nutrient, both being formed by the budding of a single polyp. The sexual polyp, or medusa, either swims away or remains attached to the colony, producing at length fertilised eggs, which yield planulæ, and these in turn the polyps which found new colonies.

Those of us who are called upon to tell this story in our regular course of teaching should not forget to produce our scyphistoma, strobila and ephyra; the interest is greatly enhanced if they are shown alive. It is not hard to maintain a flourishing marine aquarium even in an inland town, and a scyphistoma may be kept alive in an aquarium for years, budding out its strobila every spring.

Alternation of generations, when first announced, was taken to be a thing mysterious and unique. Chamisso brought in the name, and explained that he meant by it a metamorphosis accomplished by successive generations, the form of the animal changing not in the course of an individual life, but from generation to generation (*forma per generationes, nequaquam in prole seu individuo, mutata*). Sars adopted Chamisso's name and definition. Steenstrup a little later collected and discussed all the examples which he could discover, throwing in a number which have had to be removed again, as not fairly comparable with the life-histories of Salpa and Aurelia. He emphasised the alternation of budding with egg-production, and the unlikeness in form of the asexual and sexual stages. Like Chamisso, he carefully distinguished between development with metamorphosis

[1] Leuckart (*Zeits. f. wiss. Zool.*, Bd. III. p. 181) remarks that elongate animals tend to divide transversely or to bud axially, while broad animals tend to divide longitudinally or to bud laterally. The question has been raised more than once whether the division of the strobila is not really a case of budding. Leuckart shows that budding and fission cannot be separated by any definition; they pass insensibly into one another. (*Wagner's Handb. d. Physiol.*, art. 'Zeugung.')

and alternation of generations. All three naturalists, Chamisso, Sars and Steenstrup, laid stress on this point. In an insect, they would have said, there is development with metamorphosis. The same animal passes from larva to pupa, and from pupa to imago. In Aurelia or Salpa, however, the animal which lays eggs is not the animal which buds, but its progeny. The cycle of the life-history includes two generations and many individuals.

This view has spread very widely, and if we were to judge by what is commonly taught, I think that we should recognise this as the doctrine now prevalent. It is however, in my opinion, far inferior as an explanation of the facts to that adopted by Leuckart, Carpenter and Huxley, who regard the whole cycle, from egg to egg, as one life-history. Huxley and Carpenter, differing in this from Leuckart, do not shrink from calling the whole product of the egg an animal, even though it consists of a multitude of creatures which move about and seek their food in complete independence of one another. Rather than ignore the unity of the life-history of Aurelia or Salpa, they would adopt the most paradoxical language. This attitude was forced upon them by the comparative method. They refused to study Aurelia, for example, as an animal apart; it had its near and its remoter relatives. Among these is the fresh-water Hydra, which develops without transformation, buds off other Hydras when food is plentiful, and at length becomes sexually mature. Budding is here a mere episode, which may be brought in or left out, according to circumstances. The same individual polyp which buds afterwards produces eggs. The life-history of Salpa cannot be traced with equal facility to a simple beginning, for it presents points of difficulty, on which the learned differ. In the Polychæt Worms, however, we find a beautiful gradation leading up to alternation of generations. We begin with gradual addition of new segments and increasing specialisation of the two ends of the body, the fore end becoming non-reproductive, and the hinder end reproductive. Then we reach a stage (Syllis) in which the reproductive half breaks off from the fore part, and forms (after separation) a new head, while the fore part adds new segments behind. In Autolytus the new head forms before separation, and many worms may cohere for a time, forming a long chain with heads at intervals. In Myrianida the worms break up first, and afterwards become sexually mature. We should gather from these cases that alternation of generations may arise by the introduction of a budding-stage into a development with transformation. The polyp or worm buds while young and lays eggs at a later time. The separation of the two processes of reproduction often becomes complete, each being restricted to its own place in the life-history. As a rule the worm or polyp will bud while its structure is uncomplicated by reproductive organs. It is easy to propagate some plants by cutting one of the leaves into sections, and making every section root itself, and grow into a new plant; but we can seldom do the same thing with a flower. There may therefore be a distinct advantage to particular animals and plants in dividing the life-history into two stages, an earlier budding, and a later egg-laying stage.

The advantage to be drawn from budding is easily seen in those animals which find it hard to gain access to a favourable site. Thus a Tænia [1] is very lucky when it establishes itself in the intestine. Once there, it goes on budding indefinitely. It is harder to trace the advantage in the case of many polyps, though some (Cunina, &c.) admit of the same explanation as Tænia. There are yet other cases (some Worms, Salpæ, &c.) in which our ignorance of the conditions of life renders a satisfactory explanation impossible at present.

The budded forms often differ in structure from the budding forms which produce them, and many writers and teachers make this difference part of the definition of alternation of generations. I think that Leuckart has suggested a probable explanation in his essay of 1851,[2] which is still thoroughly profitable

[1] This case is quoted by Leuckart.

[2] 'Ueber Metamorphose, ungeschlechtliche Vermehrung, Generationswechsel,' *Zeits. f. wiss. Zool.*, Bd. III. Equally important is the same author's treatise, *Ueber den Polymorphismus der Individuen oder die Erscheinung der Arbeitstheilung in der Natur*, Giessen, 1851.

reading. He attributes the peculiarities of the larva mainly to the circumstance that it is turned out at an early age to shift for itself. In the budded forms there is no such necessity. The parent has established itself on a good site which commands a sufficiency of food. Until it has done this, it does not bud at all. The young which it produces asexually need not disperse in infancy, at least until crowding sets in. The tradesman who has founded a business puts his elder boys into the shop; perhaps the younger ones may be obliged to try their luck in a distant town. The budded forms, reared at the cost of the parent, may therefore omit the early larval stages at least, and go on at once to a later or even to the final stage. Thus the head of Tænia, when it has fixed itself in the intestine, produces sexual segments; the redia of Distomum produces cercariæ or more rediæ, omitting the locomotive embryo; the scyphistoma produces ephyræ. The saving of time must often be great, and the days saved are days of harvest. Think how much a tree would lose if in the height of summer it were unable to bud, and could only propagate by seeds. If the budded forms are sexual, while the budding forms are not, there is an obvious explanation of the difference in form. Even where there is no such fundamental difference in function, the circumstances of early life are very different, and may well produce an unlikeness upon which Natural Selection may found a division of labour.

No one who tries to trace origins can rest satisfied with Steenstrup's account of alternation of generations. He makes no effort to show how it came about. Instead of considering alternation of generations as a peculiar case of development with metamorphosis, complicated by asexual reproduction,[1] he considers asexual reproduction as a peculiar case of alternation of generations.[2] He ignores all the facts which show that the alternation may have been gradually attained, an omission which is only excusable when we note that his treatise is dated 1842. He asserts dogmatically that there is no transition from metamorphosis to alternation of generations.

It is impossible to think much on this subject without falling into difficulties over the word *generation.* For my own part I believe that such words as *generation, individual, organ, larva, adult* cannot be used quite consistently in dealing with a long series of animals whose life-histories vary gradually and without end. Ordinary language, which was devised to meet the familiar and comparatively simple course of development of man and the domestic animals, is not always appropriate to lower forms, with complex and unusual histories. If we are resolved at all hazards to make our language precise and uniform, we either fall into contradictions, or else use words in unnatural senses.

Certain recent discussions render it necessary to point out that there can be no alternation of generations without increase by budding. If a single larva produces a single sexual animal, as when a pluteus changes to an Echinus, there is development with transformation, but not alternation of generations.

It is, I think, of importance to be able to resolve so peculiar a phenomenon as alternation of generations into processes which are known to occur separately, and which may have arisen imperceptibly, becoming gradually emphasised by the steady action of the conditions of life. Every startling novelty that can thus be explained extends the application of that principle which underlies the theory of Natural Selection—I mean the principle that a small force acting steadily through a long time may produce changes of almost any magnitude.

The Hydrozoa yield innumerable and varied examples of development with transformation and also of budding. They yield also the most admirable examples of division of labour. We have Hydrozoan colonies, such as a budding Hydra, in which all the members are pretty much alike, but we soon advance to differentiation of the feeding and the reproductive members. In the Siphonophora the colony becomes pelagic, and floats at the surface of the sea. Then the medusæ no longer

[1] This is a convenient short account of Alternation of Generations, but it will not apply to every case. In Hydra, for instance, there is an ill-defined alternation of generations, but no metamorphosis.

[2] *Cf.* Leuckart, *loc. cit.*, p. 183.

break off and swim away, but are harnessed to the colony, and drag it along. The colony may contain feeding polyps, which procure and digest food for the rest; swimming bells, which are attached medusæ; perhaps a float, which is a peculiar kind of swimming bell; defensive polyps (which may be either batteries of nettling cells or covering organs); and reproductive individuals. As the individuals become subordinated to the colony, and lose essential parts of the primitive structure, they pass insensibly into organs.

The life-histories of Invertebrates abound in complications and paradoxes. Thus Eucharis, one of the Ctenophors, becomes sexually mature as a larva, but only in warm weather. This happens just after hatching, when the animal is of microscopic size. Then the sexual organs degenerate, the larva, which has already reproduced its kind, grows to full size, undergoes transformation, and at length becomes sexually mature a second time.[1] There is often a striking difference between the early stages of animals which are closely related, or a strong adaptive resemblance between animals which are of very remote blood-relationship. In the Hydrozoa similar polyps may produce very different medusæ, and dissimilar polyps medusæ that can hardly be distinguished. There are insects so like in their adult state that they can only be distinguished by minute characters, such as the form and arrangement of the hairs on the legs, and yet the larvæ may be conspicuously different.[2] Annelids and Echinoderms yield fresh examples of the same thing. In Lepidoptera and Saw-flies the larvæ are very similar, but the winged insects quite different.[3] New stages may be added in one species, while closely allied species remain unaffected. In Cunina and the Diphyidæ we get combinations which strain the inventive powers of naturalists even to name. Natural Selection seems to act upon the various stages of certain life-histories almost as it acts upon species.

But the history is not always one of growing complexity. Sometimes for example a well-established medusa-stage is dropped. First it ceases to free itself, then the tentacles and marginal sense-organs disappear, then the mouth closes. In the fresh-water Cordylophora the medusa is replaced by a stalked sac filled with reproductive elements or embryos. The Lucernariæ present a single stage which seems to be polyp and medusa in one. Hydra has no medusa. It is not always clear whether such Hydrozoa as these are primitive or reduced. Even the hydroid polyp, the central stage in the normal Hydrozoan life-history, may be suppressed, and certain medusæ in both of the chief groups develop direct from the egg or planula (Pelagia, Geryonia, Ægina, Oceania). There is no stage common to all Hydrozoa except the egg. The same thing may be said of the Tunicates.

The life-history of many Arthropods is to all appearance quite simple. There emerges from the egg a spider, scorpion, or centipede (in most Chilopoda) which merely grows bigger and bigger till it is adult. But if, as in most Crustacea, the circumstances of the species call for a migratory stage, such a stage will be added. In certain Decapod Crustacea (Penæus, Leucifer) a nauplius and as many as five other stages may intervene before the final or adult stage. Some of these larval stages are common to a great many Crustacea, but none, as we now think, belong to the original phylogeny. If a resting or a winged stage is wanted, it is supplied just as easily, witness the holometabolic insects. Here again, so far as we know, there is nothing absolutely new.[4] The stages which seem new are merely exaggerations for special purposes of sections of the life-history, which were originally marked out by nothing more important than a change of skin and a swelling out of the body. Let us not suppose for a moment that it is a law of insect-development that there should be larva, pupa, and imago, or that it is a law of Crustacean development that there should be six

[1] Chun, *Die pelagische Thierwelt*, p. 62 (1887).

[2] Some species of Chironomus are referred to.

[3] Baron Osten Sacken (*Berl. Entom. Zeits.*, Bd. xxxvii. p. 465) gives two cases of Diptera, in which 'almost similar larvæ produce imagos belonging to different families.'

[4] 'Nirgends ist Neubildung, sondern nur Umbildung.'—Baer.

distinct stages between the egg and the adult. Any of these stages may be dropped, if it proves useless—either totally suppressed, or telescoped, so to speak, into the embryonic development. Lost stages are indicated by the embryonic moults of some centipedes and spiders, Limulus, many Crustacea, and Podura. The parthenogenetic reproduction of some immature insects, such as Miastor, shows a tendency to suppress later stages. Perhaps the wingless Thysanura are additional examples, but here, as in the case of Hydra and Lucernaria, we do not certainly know whether they are primitive or reduced. It seems to be easy to add new stages, when circumstances (and especially parasitism) call for them. Meloe, Sitaris, and Epicauta are well-known examples. In some Ephemeridæ the moults, which are potential stages, become very numerous, but as a curious exception to a very general rule, the last moult of all, which is usually so important, may be practically suppressed. The fly of an Ephemera may mate, lay eggs, and die, while still enveloped in its last larval skin.

Among the many cases of what one is inclined to call *rapid* adaptation to circumstances (the chief indications of *rapidity* being the very partial and isolated occurrence of remarkable adaptive characters) are those which Giard [1] has collected and compared, and which he refers to a process called by him Pœcilogony. A number of very different animals [2] produce according to habitat, or season, or some other condition closely related to nutrition, eggs of more than one sort, which differ in the quantity of nourishment which they contain and in the degree of transformation which the issuing larva is destined to undergo. The analogy with the summer and winter eggs of Daphnia, &c. cannot escape notice, and Giard connects with all these the pædogenesis of Miastor and Chironomus, and many cases of heterogony. For our immediate purpose it is sufficient to remark that the reproductive processes and the course of development are as liable to vary for motives of expediency as the form of a leg or fin. The supposed constancy (the *necessary* constancy according to some naturalists) of the embryonic stages throughout large groups, would not be hard to break down, if it were to be again asserted. Probably the doctrine is now totally abandoned; it belongs to that phase of zoological knowledge in which Meckel could declare that every higher animal passes in the course of its development through a series of stages which are typified by adult animals of lower grade, and when an extreme partisan, far inferior to Meckel both in experience and caution, could affirm that the human embryo omits no single lower stage.

The tadpole-larva, which is common in lower Vertebrates and their allies, shows the influence of adaptation as strongly as any larva that we know. We may describe the tadpole as a long-tailed Chordate, which breathes by gills and has a suctorial mouth-disc, at least during some part of its existence. It is a cheap form of larva, when reduced to its lowest terms, requiring neither hard skeleton, nor limbs, nor neck, yet it can move fast in water by means of its sculling tail. Such a tadpole appears in many life-histories, and plays many parts. The tadpole is the characteristic Tunicate larva, and in this group commonly ends by losing its tail, and becoming fixed for life. But Salpa, which is motile when adult, has lost its tadpole. Appendicularia has lost the normal adult stage if it ever had one, and its tadpole becomes sexually mature. The same thing seems to have happened to many Amphibia, whose tadpoles acquire legs, become sexually mature, and constitute the normal adult stage. The Lamprey, as Balfour and others have recognised, is another kind of sexually mature tadpole. Thus the tadpole may act as larva to a sea-squirt, fish (Acipenser, Lepidosteus, Amia), or frog; it may also constitute the only remaining stage in the free life-history.

The lower and smaller animals seem to show beyond others the prevalence of adaptive features. They offer visible contrivances of infinite variety, while they are remarkable for the readiness with which new stages are assumed or old ones dropped, and for their Protean changes of forms, which are so bewildering that

[1] C. R. 1891, 1892.

[2] *E.g.* Crustacea (Palæmonetes, Alpheus), Insects (Musca corvina, some Lepidoptera and Diptera), an Ophiurid (Ophiothrix), a Compound Ascidian (Leptoclinus), &c.

many Worms, for instance, cannot as yet be placed at all, while many larvæ give no clue to their parentage. These lower and smaller animals show beyond others a tendency to multiply rapidly, and to break away from one another in an early stage. The tendency is so strong in the microscopic Protozoa that it enters into the definition of the group. Fission, budding, alternation of generations, and spore-formation (as in Gregarina) are ultimately due to the same tendency.

Weak animals are almost inevitably driven to scatter, and to make up by their insignificance, their invisibility, and their powers of evasion for the lack of power to resist. It is a great thing to a Hydrozoan colony that if one polyp is bitten off, others remain, that no enemy can possibly devour all the medusæ liberated from one colony, or all the planulæ liberated from one medusa. Low organisation gives very special facilities for extreme division. There are animals and plants which multiply greatly as a consequence of being torn to pieces or chopped small. (Chigoe, some Fungi, &c.)

Small animals are usually short-lived. Many complete their life-history in a few weeks. Those which last for so long as a year are often driven, like annual plants, to adapt every detail of their existence to the changing seasons. The naturalist who explores the surface waters of the sea with a tow-net soon learns that the time of year determines the presence or absence of particular larvæ. It is probably as important to an Aurelia as to a butterfly that it should tide over the storms of winter by means of a sedentary and well-protected stage. Any one who keeps scyphistoma in an aquarium will remark how small it is, how it creeps into crevices or the hollows of dead shells. But when the depth of winter is past, it pushes out its strobila, which in spring liberates ephyræ. These rapidly enlarge, and by August have grown from microscopic discs to jelly-fishes a foot across.

The intelligence of many small animals is very low. They go on doing the thing that they have been used to do, the thing that has commended itself to the experience of many generations. They are governed by routine, by that inherited and unconscious power of response to external stimulus, which we call instinct. But there are some notable exceptions. Of all small animals, insects seem to show the greatest flexibility of intelligence.

There is one large group of animals which is in striking contrast to nearly all the rest. Vertebrates, and especially the higher Vertebrates, are usually big and strong. They rely upon skill, courage, or some other product of high organisations, rather than upon numbers and fertility. Vertebrates swallow many other animals, together with their living parasites, but are rarely swallowed alive or fresh by Invertebrates. This fact of nature has led to many consequences, among others to this, that many parasites which pass their earlier stages in the bodies of Invertebrates only attain sexual maturity in a Vertebrate host. The complexity of the structure of a Vertebrate precludes the possibility of multiplication by breaking-up or budding, and they multiply only by egg-laying or strictly analogous processes. The higher Vertebrates live so long that the accidents of a particular year or a particular season are not of vital importance. Hence seasonal transformation is almost unknown; the quadruped or bird may choose the warm months for rearing the family, or celebrate the pairing season by getting a new suit of feathers, or grow a thicker coat against the cold of winter, but that is all. No Vertebrates perish regularly at the approach of winter, leaving only batches of eggs to renew the species in spring, nor is their structure profoundly modified by the events of the calendar (the frog is a partial exception). One minor cause of transformation, which affects the life-history of many polyps, worms and insects, is thus removed. Vertebrates often take care of their young, and the higher Vertebrates bring forth few at a time. For this reason among others they rarely afford examples of free larvæ. Such Vertebrate larvæ as we do find, conform to the Vertebrate type. It is often impossible to predict what adult will develop from an Invertebrate larva, but no one could hesitate to rank an Ammocoetes, a Leptocephalus, or a tadpole among the Vertebrates.

It accords with this strength and mastery that Vertebrates, and especially the higher Vertebrates, should be more stable, more conservative, less experimental than other animals. They retain ancient structures long after they have ceased to

be useful. The gill-clefts, gill-arches, and branchial circulation are good examples. Though not functional in Sauropsida and Mammalia, they never fail to appear in the course of the development. Yet the Sauropsida and the Mammalia are positively known to go back to the earliest secondary and late palæozoic times. Ever since the beginning of the secondary period at least, every reptile, bird, and mammal has continued to pass through a stage which seems obviously piscine, and of which no plausible explanation has ever been offered, except that remote progenitors of these animals were fishes. Could not Natural Selection, one is tempted to ask, have straightened the course of development during lapses of time so vast, and have found out less roundabout ways of shaping the tongue-bone and the ossicles of the ear? Either it costs nothing at all to pursue the old route, or it costs nothing which a higher Vertebrate will ever miss. The second alternative seems to me the more likely. The Sauropsida and Mammalia, in comparison with other animals, are particularly well off, and like wealthy housekeepers, they do not care what becomes of the scraps. It is, I fancy, different with many fishes, which show by their numerous eggs, the occasional presence of peculiar immature stages, and some other slight hints, that their life is a hard one.

The presence in the developing reptile, bird, or mammal of piscine structures which are no longer useful has been ascribed to a principle called Recapitulation, and Haeckel lays it down as a fundamental biogenetical law that the development of the individual is an abbreviated recapitulation of the development of the race. If I had time to discuss the Recapitulation Theory, I should begin by granting much that the Recapitulationist demands—for instance, that certain facts in the development of animals have an historical significance, and cannot be explained by mere adaptation to present circumstances; further, that adaptations tend to be inherited at corresponding phases both in the ontogeny and the phylogeny. I am on my guard when he talks of *laws*, for the term is misleading, and ascribes to what is a mere general statement of observed facts the force of a command. The so-called laws of nature (a phrase to be avoided) may indeed enable us to predict what will happen in a new case, but only when the conditions are uniform and simple—a thing which is common in Physics, but very rare in Biology. I diverge from him when he says that 'each animal is compelled to discover its parentage in its own development,' that 'every animal in its own development repeats this history, and climbs up its own genealogical tree.' When he declares that 'the proof of the theory depends chiefly on its universal applicability to all animals, whether high or low in the zoological scale, and to all their parts and organs,'[1] I feel persuaded that, if this is really so, the Recapitulation Theory will never be proved at all. The development, so far as it has yet been traced, of a Hydra, Peripatus, Beetle, Pond-mussel, Squid, Amphioxus, Chick or Mammal tells us very little indeed of the history of the races to which they belong. Development tells us something, I admit, and that something is welcome, but it gives no answer at all to most of the questions that we put. The development of a Mammal, for instance, brings to light what I take to be clear proof of a piscine stage; but the stage or stages immediately previous can only be vaguely described as Vertebrate, and when we go back further still, all resemblance to particular adult animals is lost. The best facts of the Recapitulationist are striking and valuable, but they are much rarer than the thorough-going Recapitulationist admits; he has picked out all the big strawberries, and put them at the top of the basket. I admit no sort of necessity for the recapitulation of the events of the phylogeny in the development of the individual. Whenever any biologist brings the word *must* into his statement of the operations of living nature, I look out to see whether he will not shortly fall into trouble.

This hasty review of animal transformations reminds me how great is the part of adaptation in nature. To many naturalists the study of adaptations is the popular and superficial side of things; that which they take to be truly scientific

[1] The quotations are from the late Professor A. Milnes Marshall's Address to Section D., *Brit. Assoc. Rep.*, 1890, which states the Recapitulationist case with great knowledge and skill.

is some kind of index-making. But we should recognise that comparatively modern adaptations may be of vital importance to the species, and particularly luminous to the student because at times they show us nature at work.

I am accustomed to refer such adaptations to the process of Natural Selection, though if any one claimed to explain them by another process, I should, for present purposes, cheerfully adopt a more neutral phrase. There are, I believe, no limits to be assigned to the action of Natural Selection upon living plants and animals. Natural Selection can act upon the egg, the embryo, the larva, and the resting pupa, as well as upon the adult capable of propagation. It can even influence the race through individuals which are not in the line of descent at all, such as adults past bearing or the neuters of a colony. The distinction between historical and adaptive, palingenetic and cœnogenetic, is relative only, a difference not of kind but of degree. All features are adaptive, but they may be adapted to a past rather than to a present state of things; they may be ancient, and deeply impressed upon the organisation of the class.

In Biology facts without thought are nothing; thought without facts is nothing; thought applied to concrete facts may come to something when time has sorted out what is true from what is merely plausible. The Reports of this Association will be preserved here and there in great libraries till a date when the biological speculations of 1897 are as extinct as the Ptolemaic Astronomy. If many years hence some one should turn over the old volumes, and light upon this long-forgotten address, I hope that he will give me credit for having seen what was coming. Except where the urgent need of brevity has for the moment been too much for scientific caution, I trust that he will find nothing that is dogmatic or over-confident in my remarks.

The following Reports and Papers were read:—

1. *Report on Investigations made at the Zoological Station, Naples.* See Reports, p. 353.

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2 *Report on Investigations made at the Laboratory of the Marine Biological Station, Plymouth.*—See Reports, p. 370.

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3. *On the Naples Marine Station and its Work.* *By* Dr. ANTON DOHRN.

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4. *On a proposed Lacustrine Biological Station for Canada.* *By* Professor R. RAMSAY WRIGHT.

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5. *Origin of Vertebrata.* *By* Professor C. S. MINOT.

FRIDAY, AUGUST 20.

The following Papers and Reports were read:—

1. *Reconstruction and Model of* Phenacodus primævus, *Cope. By* Professor HENRY FAIRFIELD OSBORN.

The famous skeleton of *Phenacodus,* belonging to the Cope Collection, which came into the possession of the American Museum of Natural History in 1895, has been entirely freed from the matrix and remounted in such a manner that every part can be removed for study. This remounting gives quite a different conception of the animal from that presented in the original mounting, as illustrated before the Section in an enlarged photograph of the fossil skeleton and a wax model by Charles Knight. *Phenacodus* is digitigrade as the tapir. Its proportions are very peculiar and widely different from those of any modern ungulate, consisting of an extremely small head, short neck, short fore-limbs, long hind-limbs, powerful hind-quarters and tail, and upwardly arched back. *Phenacodus* is not ancestral to any of the modern Ungulata because its ancestor *Euprotogonia* is similarly specialised, although found in the basal Eocene. These animals, however, give us a picture of the true ancestral ungulate type and forcibly demonstrate the derivation of the hoofed from the clawed animals. The model of *Phenacodus* shows its many points of likeness to the general build of the Creodonta or ancient Carnivora.

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2. *On Skeletons and Restorations of Tertiary Mammalia. By* Professor HENRY FAIRFIELD OSBORN.

This paper, illustrated by numerous photographs of the mounted skeletons and of Charles Knight's restorations, set forth the special methods instituted by the author in the American Museum of Natural History. The field work which began six years ago is planned as a complete *faunal survey* of the ancient Tertiary lakes, the Eocene and Oligocene being now nearly complete, and future work extending into the Miocene and Pliocene and back into the Mesozoic. Careful records of horizontal distribution of species are preserved and numerous new faunal subdivisions have already been clearly defined. Two other features of the field work are the extremely skilful and thorough methods of collection and the efforts made to secure complete skeletons suitable for mounting, the ultimate object being to secure and exhibit every stage in the development of the more important types. Ten complete skeletons have already been mounted as follows: *Protorohippus, Hyrachyus, Palæosyops, Titanotherium, Phenacodus, Coryphodon, Aceratherium, Metamynodon,* representing the ungulates; *Patriofelis* and *Hoplophoneus,* representing the unguiculates. The special features of the museum work are the immediate cataloguing of the collections, which now include upwards of 10,000 individuals, and their division into a study and exhibition series, both of which are readily accessible to investigators. The mounting of the skeletons vastly increases their interest to the general public. Each skeleton, as exhibited, will be accompanied by a model representing its former muscular proportions and by a large coloured restoration giving an idea of its appearance when alive, its habits and environment. A double set of labels will also be adopted, separating the popular from the purely scientific information. The methods of field collection are popularised by means of large coloured transparent photographs hung in the windows, taken in the field especially for this purpose.

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3. *Oysters and the Oyster Question.* *By* Professor W. A. Herdman, *F.R.S.*—See Reports, p. 363.

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4. *The Amblyopsidæ, the Blind Fish of America.* *By* Dr. C. H. Eigenmann.

The underground regions of North America are inhabited by a number of blind aquatic vertebrates.

These are *Typhlomolge* from Texas, *Typhlotriton* from Missouri, *Gronias nigrilabris* from Pennsylvania, *Amblyopsis spelæus* from Kentucky and Indiana, *Typhlichthys subterraneus* from Kentucky, Alabama, and Indiana, and an undescribed species, *Typhlichthys rosæ*, from Missouri.

A considerable area of South Central Indiana is drained entirely by underground streams in which Amblyopsis is abundant.

It has the general appearance of skinned catfish, is well balanced in the water, and has broad fins.

The chief points of interest in Amblyopsis are the eyes, the skin, and the tactile organs. Since, however, all the published accounts concerning this fish are more or less worthless, some other points of interest may be mentioned.

Amblyopsis has been recorded as a surface feeder, but it secures its food at the bottom. Its abundant tactile organs about the head enable it to exactly locate a crawling or moving object if a short distance from its head. A rod held in the hand is readily perceived by the slight vibrations when the fish is about an inch away. A young one reared in the light was able invariably to perceive the direction a rod was approaching it, and to swim intelligently away.

Although the eyes are entirely incapable of receiving impressions, the fish reacts negatively to light. This reaction is not caused by any particular colour of the spectrum. It is not a matter of heliotropism, for the direction of the light has nothing to do with the reaction.

The eye in the adult has no connection with the brain. The lens is composed of a few inconspicuous cells. The vitreous humour is gone, and the eye, in consequence of the absence of a hyaloid, vitreous body, and practically the total absence of a lens, has collapsed, so that the ganglionic layer forms a solid core of cells. The inner reticular layer is well developed. The layers outside of this to the external limiting membrane have been reduced to a layer of cells about two deep. The pigment has in some of the best eyes retained its normal thickness. Cones are present. The sclera is represented by one or more cartilaginous masses.

In the number and arrangement of the tactile organs it is not materially different from Chologaster, which can certainly see.

The steps of degeneration can be followed by comparing the eyes of Zygonectes, Chologaster, Typhlogobius, and Amblyopsis. The lens is the last to be affected, but when it once begins it degenerates very rapidly, disappearing in some cases during the life time of an individual, *e g.*, Typhlogobius.

Amblyopsis is universally considered as viviparous. This it is not. The female lays the eggs under her own gill-covers, which are very wide. Here the young are reared through their larval stages. When the female at this time is handled the young will squirm out. This fact has given rise to the supposition that the fish is viviparous.

The absence of pigment causes the blood to give Amblyopsis a yellowish tint in the thinner parts, such as the fins, while in the thicker parts the colour is pink.

Pigment cells are abundant in the larva, and are not at all rare in the skin of the adult, but they contain little pigment.

It is a matter of general observation that the pigment diminishes in the absence

of light in many fishes. A striking instance is the lower side of flatfishes. It is also known that Proteus, when exposed to the light, becomes dark (Osborn), and that the lower side of a flounder, if exposed to the light, may become pigmented (Cunningham).

Now, since pigmentation cannot be of any selective value in dark places, the disappearance of pigment cannot be attributed to natural selection; nor can the matter of economy have given selection a chance to remove the pigment. Is the lack of pigment, then, a characteristic reacquired with each individual? It is not, for in a young fish kept for ten months in the light the absence of pigment was as marked as in the adult.

We apparently have here an acquired characteristic, the depigmented condition of the chromatophores hereditarily established.

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5. *The Origin of the Mammalia.* *By* Professor HENRY FAIRFIELD OSBORN.

The Tertiary and Recent placentals have been divided by the author into Ceneutheria and Meseutheria.

The former include the higher types, progressive and specialised, mainly during the Eocene and Oligocene periods. The latter include the lower types, persistent and primitive, specialised mainly during the Mesozoic period, and with the exception of the Lemaroidea, Insectivora, and Ganodonta, dying out early in the Tertiary. Among these Meseutheria are included the Creodonta, Tillodontia, Insectivora, Lemuroidea, Condylarthra, and Amblypoda. The most distinctive feature of their evolution is the retarded brain development, the *inertia* or persistence of many primitive characters lost among the Ceneutheria, as well as the fact that they appear substantially in their fully specialised form in the base of the Eocene, and are thus distinctively the Mesozoic placentals. The known upper Cretaceous mammals are substantially of the same Eocene Meseuthere type, and contain also certain Multituberculata (which may be regarded as Prototheria) and possibly also certain marsupials.

The Lower Cretaceous or Upper Jurassic (Purbeck) Mammalia embrace also Multituberculates (? Prototheria), Triconodonts (Metatheria), and Insectivora primitiva (Meseutheria). The latter may have given rise to the later Meseutheria, and thus indirectly to the Ceneutheria, although no absolute links are as yet established connecting the Ceneutheria with the Meseutheria, and the latter are even more primitive than the known forms of Metatheria or Marsupialia.

The combined characters of the three above-mentioned types of Jurassic mammals led the author in 1891 to the conclusion that the Hypotheria or Promammalia would be found to possess a heterodont dentition, consisting of I. 4, C. 1, P. 4–5, M. 8. Also that all the Mammalia, multituberculate as well as trituberculate, would be found to be originally derived from a trituberculate type of molar dentition.

In the meantime Baur has shown that Cope's *Pelycosauria,* a division of the Theromorpha, which Cope believed to be ancestral to the mammals, must be entirely removed from this position. The discoveries of Seeley in the Permian of South Africa (Karoo Beds) show that the *Theriodontia* possess most of the characters which we may expect to find in the ancestors of the Mammalia, mingled with many distinctively reptilian characters. Among these Theriodonts the herbivorous division, or Gomphodontia, presents many analogies to the Multituberculata, while the carnivorous Cynodontia are similarly analogous both to the Protodonta (Osborn) of the American Triassic and to the Triconodonta, or ancestral trituberculates, the specialised dental formula agreeing closely with that postulated for the

Hypotheria. The Gomphodontia, however, with the exception of *Tritylodon*, show a marked tritubercular pattern in their superior molars (especially *Diademodon mastacus*) and tend to confirm the author's hypothesis that the multituberculates are of tritubercular origin.

The general conclusion is that the Theriodontia stand nearer the ancestral mammalia Prototheria, Metatheria, and Meseutheria than any other known division of the Reptilia.

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6. *Description of Specimens of Sea-trout, Caplin, and Sturgeon from Hudson Bay. By* Professor EDWARD E. PRINCE, *Ottawa.*

The author referred to the special interests attaching to specimens illustrative of the fish fauna of Hudson Bay, the faunistic resources of which are almost wholly unknown.

Distinguished explorers like Dr. R. Bell, Mr. J. Burr Tyrrell, Mr. A. P. Lowe, and others, chiefly members of the staff of the Geological Survey of Canada, have gathered information regarding the fish in the remote northern areas referred to; their special work, of a geological and geographical character, prevented systematic zoological investigations. The specimens described by the author were placed in his hands by Dr. Bell and Mr. Lowe.

The salmon-trout from Ungava Bay is the *Salmo Hearnii*, originally described in Franklin's first journal. It is really a *Salvelinus*, and is no doubt the *Salvelinus alpinus stagnalis* of Jordan and Evermann. It must be noted, however, that the *Salmo stagnalis* of Fabricius (1780), inhabiting small lakes in Greenland, is non-migratory. If it be non-migratory, or if it does migrate to the sea, and then becomes, as is stated, of a plain silvery colour, the specimen under review is not identical with it. At any rate, the present specimen, taken, as Mr. Lowe states, on the east coast of Hudson Bay to the north of Cape Jones, and very abundant in the streams entering Ungava Bay and along the northern coast of Labrador, is characterised by the three features mentioned below. First, it is migratory and captured in vast numbers in tidal waters in Ungava Bay and other localities. Secondly, it exhibits large disc-like spots of a pale flesh tint, rather larger than a pea in circumference, and extending from the shoulder to the tail, and slightly above the lateral line. Thirdly, the scales are exceedingly small, somewhat deeply imbedded in the integument, and numbering at least 250 along the lateral line.

The typical *alpinus* (Sailling) exhibits about 200 scales along the lateral line, has twelve rays in the anal fin, and shows a white anterior margin on the paired fins. In these three points the present specimen differs, nor is it like *Salvelinus alipes*, which has twelve or thirteen rays in the first dorsal fin, 126 scales in the lateral line, according to Dr. Suckley. Günther regards *S. alipes* as identical with *S. stagnalis*. It may be added that the present specimen has the following fin-ray formula:—P. 14, D. 13, V. 11, A. 10, the fins are plain, the dorsum of a dark olive green tint, and the tail truncate or very slightly forked. The weight is from 3 lb. to 18 lb. The specimen of caplin is a somewhat diminutive dried example, but a careful examination showed that it differed in no respect from the caplin (*Mallotus villosus*) which abounds in the Gulf of St. Lawrence. The presence of caplin in Hudson Bay might be taken as an indication that cod occur there. It is the favourite food of the cod at certain seasons.

The specimen of sturgeon from Hudson Bay is *Acipenser sturio*, L., though the specimen is very young, less than six inches in length, and the external features are known to change materially with the attainment of maturity. In young sturgeon the snout, as a rule, is long and attenuated, the body slender, the enamel plates highly developed, and the spines prominent and hooked. This example has: dorsal plates 14, lateral 35, ventral 11; and the fin-rays are: dorsal fin 36, anal 20. These details in other species are as follows:—

	Shields			Fin-rays	
	D.	L.	V.	D.	A.
Acipenser transmontanus .	11–12	36–50	10–12	45–48	28–30
A. medirostris	9–11	26–30	7–10	33–35	22–28
A. rubicundus	11–16	30–39	8–11	35	26
A. brevirostris	8–11	22–33	6– 9	41	22
A. sturio	10–14	27–36	8–11	38	27

The specimen agrees, therefore, with *Acipenser sturio*, L.

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7. *On the Esocidæ (or Luciidæ) of Canada.* *By* Professor E. E. PRINCE, *Ottawa.*

The author stated that a few weeks before the date of the meeting of the British Association he had the good fortune to receive a specimen of a pike from Dr. Coutlee, of Sharbot Lake, Ontario. It appeared to be a new and undescribed species, and differed in many features from the recognised species found in the waters of the Dominion, which were five in number. Briefly stated, these features are respectively—

	Branchio-stegals	Dorsal Fin-rays	Anal Fin-rays	Length	Scales of Lat. Line
Esox americanus, Gmelin .	11–13	11–12	11–12	12 in.	105
E. vermiculatus, Le Suer .	11–13	11–12	11–12	12 in.	105
E. reticulatus, Le Suer . .	14–16	14	13	30 in.	125
E. lucius, Linn.	14	16–17	13–14	30–50 in.	123
E. nobilior, Thomp. . . .	17–19	17	15	96 in.	150

It may be added that in the three first-named species the cheeks and gill-cover are completely clothed with scales; but in *Esox lucius* the lower half of the gill-cover is bare, and in the Maskinonge (*E. nobilior*) both the cheek and gill-cover are scaleless over the lower half.

The fish now described for the first time agrees with *E. lucius* in having the lower half of the gill-cover scaleless; but it differs from all the above species in other features. Thus the branchiostegals are 15, the dorsal fin-rays 19, the anal fin-rays 16, and the scales are small, viz., 130 or more in the lateral line. This line is deeply pigmented, in contrast to *E. lucius*, in which it is indistinctly marked. The colouration is very distinctive. Unlike the whitish spotted colouration upon a grey or dark green ground of *E. lucius* or the blackish spotted marking upon a light grey or green ground colour as in the Maskinonge, or the barred or reticulated pattern upon *E. americanus* and *E. reticulatus* respectively, this fish exhibits upon the back and down the sides a bright metallic green, almost of an emerald tint, finely mottled with black. All the fins are plain grey, with a brick red tint towards the margin. A glistening purple blue colour forms six or seven striking patches on the head and gill-cover; viz., one below the eye, one above the eye, one above the eye posteriorly situated, one on the cheek, one at the upper posterior corner of the gill-cover, one just above the upper edge of the branchiostegal membrane, and one on the flattened portion of the maxillary. The chin is jet black. The fish is somewhat restricted in range, and is locally called the blue pike.

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8. *Recent Additions to the Fish Fauna of New Brunswick.* *By* Dr. PHILIP COX.

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9. *Theories of Mimicry as illustrated by African Butterflies.* *By* EDWARD B. POULTON, *M.A., F.R.S., Hope Professor of Zoology, Oxford.*

H. W. Bates, in his epoch-making paper ('Trans. Linn. Soc.,' vol. xxiii. 1862), first gave an intelligible theory of mimicry, and accounted for the superficial resemblances which had been known for so long by supposing that the most dominant, well-defended, and conspicuous forms in a country become the models towards which natural selection leads many of the weaker hard-pressed species in the same locality. The material on which Bates' theory was formed was confined to tropical America, and his generalisation remained incomplete until it could be applied to the other great tropical regions. This want, however, was soon supplied by A. R. Wallace for the East ('Trans. Linn. Soc.,' vol. xxv. 1866), and by Roland Trimen for Africa ('Trans. Linn. Soc.,' vol. xxvi. 1870).

In Bates' original paper a certain class of facts—frequently mentioned and abundantly illustrated—cannot be explained under his theory of mimicry. This is the strong resemblance which is apt to exist between the dominant forms themselves, and which is as minute and as remarkable as the resemblance of the weaker for the stronger species. Bates pointed out that this was unsolved by his theory, and both he and Wallace were compelled to suggest the direct action of some unknown local influence as the possible cause. There the matter rested until Fritz Müller, in a paper published in 'Kosmos' for May 1879, suggested an explanation, viz., that the dominant forms gain an advantage by this resemblance, inasmuch as it facilitates the education of their enemies by giving them fewer patterns to learn. The necessary waste of life by which the education of young birds, &c., is brought about is here divided between the various species of a closely convergent group, instead of being contributed by each member independently. The chief sub-families of butterflies which in tropical America appear to be specially distasteful to insect-eating animals, and which are specially mimicked by others, are the *Danainæ, Ithomiinæ, Heliconinæ,* and *Acræinæ.* Of these the second and third are confined to this part of the world. The resemblances which Fritz Müller explained are those which occur very commonly between the *Danainæ, Ithomiinæ, Heliconinæ,* and less commonly the *Acræinæ* of any locality. In order to complete this theory it was necessary to test its application in other parts of the world.

In the East the butterflies which take the place of the four above-named sub-families belong almost exclusively to the *Danainæ,* the *Acræinæ* being represented by very few species. The *Danainæ* are, however, extremely rich in species, and F. Moore first pointed out in 'Proc. Zool. Soc.,' 1883, p. 201, that there is the same relationship between the species of this dominant group that obtains between those of tropical America. Not only do *Danainæ* of very different genera closely resemble each other, but there is often a strong likeness between the species belonging to the two chief divisions of the sub-family—the *Danaina* and *Euplœina.* As in America, these resemblances are always between the species of the same locality.

While, however, Müller's theory received full confirmation from the facts observed in India and the tropical East generally, no attempt has been made until now to apply it to the African lepidopterous fauna. I have therefore examined this fauna from the Müllerian standpoint, and find that in it too the same relationships can be traced.

The dominant distasteful groups of Africa are the *Acræinæ,* which have their metropolis here, and the *Danainæ.* The latter are chiefly represented by the species of the peculiar African genus *Amauris,* and by the abundant and widespread *Danais* (*Limnas*) *chrysippus.* I first looked for evidence of convergence between the *Acræinæ* and *Limnas chrysippus,* and soon found what appeared to be evident traces of it. Such species as *Planema esebria* (certain forms of), *Acræa petræa* (female), *A. oppidia,* and, above all, *A. encedon* (*lycia*) bear a considerable

resemblance to *L. chrysippus*, inasmuch as all of them possess a dark tip to the fore wing crossed by a white bar, as in the Danaine butterfly. Looking at the near allies of these species and at the *Acræinæ* as a whole, we may feel confident that this black-and-white tip is not an ancestral character of the group, but a comparatively recent modification. Again, the fact that this character is sometimes more strongly developed in, and sometimes confined to, the female sex agrees with the corresponding relationships in other parts of the world, and furthermore supports the conclusion as to the recent acquisition of the markings.

Convergence between the *Acræinæ* and *Danainæ* of the genus *Amauris* was next looked for and many examples found. Thus *Acræa johnstoni* of East Central Africa certainly suggests the appearance of one of the *echeria* group, such as *A. hanningtonii*, found in the same locality; while in West Africa *Acræa lycoa* resembles the black-and-white *Amauris damocles* and *A. egialea*. Similar resemblances in the West are to be seen between the large black-and-white females of the numerous species of the Acræine genus *Planema* and other Acræas in the same locality, such as *A. carmentis* (female) and *A. jodutta* (female), while the species referred to, of both Acræine genera, bear some considerable resemblance to an abundant West African black-and-white Danaine—*Amauris niavius*. Similar relationships occur in the South-East, where Acræas, such as *Planema esebria* (white form of female) and *P. aganice* bear considerable resemblance to the abundant black-and-white Danaines—*Amauris ochlea* and *A. dominicanus*.

It was of great interest to prove that the members of these convergent groups occur, not only in the same place, but at the same time. Mr. Guy A. K. Marshall has kindly done this work, sending me several groups captured at one place in a single day. At Malvern, near Durban, Natal, on March 6, and again on March 30, 1897, he captured *Limnas chrysippus* and several species of *Acræa*, with the black-and-white tip to the wing. On March 27 he captured, in the same locality, the black-and-white Planemas (*Acræinæ*) *P. esebria* and *P. aganice*, together with an abundant black-and-white *Neptis* (*N. agatha*) and a closely similar day-flying moth, *Nyctimeris apicalis*. It is very probable that these latter forms do not mimick in the Batesian sense, but are themselves specially defended and fall into a Müllerian group. Mr. Marshall did not, on that day, capture any of the black-and-white *Danainæ*. Mr. D. Chaplin, however, on April 5, 1896, obtained at Berea, a suburb of Durban, *Amauris ochlea* and *Planema aganice*, as well as *Limnas chrysippus*, with two species of convergent Acræas (*A. encedon* and *A. petræa*). Mr. F. D. Godman and Mr. O. Salvin have kindly presented these specimens to the Hope Collection at Oxford.

I think it must be admitted that there is now strong evidence for the same convergence between specially protected abundant African species from the same locality as that which is already well known in the tropical East and in tropical America. Various degrees of perfection exist, and it is in every way probable that the resemblance of some members to the standard of their group is not of long standing, and will improve in the future.

Other facts in the colouring of African Lepidoptera also support this interpretation. Thus certain *Lycænidæ* of the genera *Pentila* and *Alæna* are known to fly very slowly, and in the case of the latter to feign death when captured—characteristics of unpalatable forms. While they thus differ in habits from Lycænids generally, they also differ entirely in their appearance, which rather suggests that of an *Acræa*. The same is true of moths belonging to many groups, and perhaps of the abundant butterflies of the genus *Byblia*. Similarly the large group of Lepidoptera, which has for its centre the abundant day-flying moths of the genus *Aletis*, appears to be moulded upon the colouring and pattern of *Limnas chrysippus*, differing only in an even greater conspicuousness, due to the white spots or rings on the black body, and the highly developed black-and-white border to the hind wing. It is probable that the common species of the genus *Euphædra*, which form some of the most conspicuous members of this group, are themselves specially protected. To take one more example, certain species of the Pierine genus *Mylothris* are rendered specially conspicuous by the interrupted black border to the hind wings, the interruptions extending along the hind margin of the fore wings. A

white butterfly with such a border becomes an extremely conspicuous object, and this appearance of *Mylothris* is mimicked, more or less perfectly, by species from a number of Pierine genera, such as *Nepheronia, Belenois, Callosune,* &c. This is usually explained as an example of true Batesian mimicry, but it is, perhaps, more probable that the *Pierinæ* are very largely a specially protected group, many of the genera of which, so to speak, combine their advertisements, and thus share between them the loss of life which must necessarily ensue during the education of each generation of their enemies.

I think sufficient evidence has been brought forward to show that the theory of mimicry, or rather of common warning (synaposematic) colours, which will always be associated with the name of Fritz Müller, may claim abundant examples in Africa as well as in the other parts of the world in which it has already been proved to hold.

10. *On the Surface Plankton of the North Atlantic.* *By* W. Garstang, *M.A.*

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11. *Remarks on* Branchipus stagnalis. *By* A. Halkett.

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12. *Report on Zoological Bibliography and Publication.*

See Reports, p. 359.

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13. *Report on the Index generum et specierum Animalium.*

See Reports, p. 367.

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14. *Report on the Zoology and Botany of the West Indian Islands.*

See Reports, p. 369.

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15. *Interim Report on Bird Migration in Great Britain and Ireland.*

See Reports, p. 362.

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16. *Report on African Lake Fauna.*—See Reports, p. 368.

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17. *Report on the Zoology of the Sandwich Islands.*

See Reports, p. 358.

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18. *Report on the Necessity for the Immediate Investigation of the Biology of Oceanic Islands.*—See Reports, p. 352.

SATURDAY, AUGUST 21.

The Section did not meet.

MONDAY, AUGUST 23.

The following Papers were read:—

Protective Mimicry as Evidence for the Validity of the Theory of Natural Selection. By EDWARD B. POULTON, *M.A., F.R.S., Hope Professor of Zoology, Oxford.*

Several suggestions have been put forward to account for the superficial resemblances between animals, especially insects, occupying the same geographical area. It has been suggested, and indeed strongly maintained, that food, climate, or some other chemical or physical influence of the locality may have supplied the cause. On the other hand, many naturalists consider that the facts cannot be interpreted by any of these suggested causes, and only receive an intelligible and probable explanation in the theory of natural selection. This theory supposes that the resemblance is advantageous in the struggle for existence, the weaker forms being shielded by their resemblance to the strong and well-defended species (mimicry of H. W. Bates), or the latter gaining by a resemblance which enables their local enemies more easily—and thus with a smaller waste of life—to recognise and avoid them (mimicry of Fritz Müller). The present paper directs attention to certain facts commonly associated with mimetic resemblance which receive a ready explanation upon the theory of natural selection as the efficient cause, but, on the other hand, constitute a serious difficulty in the way of any other theories as yet brought forward.

Natural selection, as is well known, acts upon *any* variations, whatever they may be, which are in the advantageous direction, and are at the same time not injurious in themselves. When the end to be gained (in this case the attainment of a superficial resemblance) is common to a variety of distantly related species possessing entirely different constitutional tendencies, we may feel confident that an approach brought about by natural selection will be by extremely diverse paths of variation. Under natural selection we might predict that such a common end would be reached by great diversity of means, while under the other hypotheses mentioned above a result of the kind is inexplicable. Hence the facts of the case should act as a convenient test between these rival suggestions.

First as to colour. We know but little of the chemical nature of the pigments made use of in mimetic resemblance. One case, however, has been investigated by Gowland Hopkins—viz., the bright tints by which certain S. American *Pierinæ* have come to resemble *Heliconinæ* and *Ithomiinæ* in the same locality. Gowland Hopkins has shown that these close resemblances in colour and pattern are produced by pigments which are characteristic of the *Pierinæ*, and of an entirely different chemical nature from those of their models.

Another very interesting case is that of resemblance to ants. Ants are mimicked more or less closely by a great variety of insects and by spiders. In

some cases we find the resemblance brought about by actual alterations in the shape of the body (spiders and many insects), which is modified into a superficial resemblance to the Hymenopteron. In an Acridian—*Myrmecophana fallax*—the shape of an ant is, as it were, painted in black pigment upon the body of the insect, which is elsewhere light in colour and, as it is believed, inconspicuous in the natural environment. In a certain group of Homoptera—the Membracidæ—some of the S. American species closely resemble ants. The Membracidæ are characterised by an enormous growth from the dorsal part of the first thoracic segment (pronotum), which spreads backwards and covers the insect like a shield. In these insects the form of an ant is moulded in the shield beneath which the unmodified body of the insect is concealed. These facts are only explicable by supposing that some great advantage is to be gained by resembling an ant, and that very different species have attained this end, each by the accumulation of those variations which were rendered possible by its peculiar ancestral history and present constitution—in other words, by the theory of natural selection.

A more elaborate case, which I have recently investigated, is afforded by a large group of tropical American Lepidoptera—moths as well as butterflies—which closely resemble certain common wide-spread species of the Ithomiine genera *Methona* and *Thyridia*. The appearance thus produced consists of a transparent ground with a black border to both wings, the fore wing being also divided by black transverse bars into three transparent areas—the hind wing usually into two. From a comparison with other species of the various families, &c., not altered in this direction, we know that the transparent wings are not ancestral. When we investigate the manner in which transparency has been attained, it is found to be by different methods in the different constituents of the group. Among the numerous genera of Ithomiinæ (*Methona, Thyridia, Dircenna, Eutresis, Ithomia*, &c.) the result has been attained by the reduction of the scales to a very minute size, so that they hardly interfere with the passage of light. This reduction affects the two kinds of scales which alternate with each other in the rows upon the wings of this sub-family, a common result being (*e.g.*, in *Methona* and *Thyridia*) the alteration of the more slender scales into hairs, and of the broader ones into minute bifid structures, still retaining scale-like proportions in spite of their extremely small size. In others, again, the two kinds of scales are reduced respectively to simple and **Y**-shaped hairs, which regularly alternate along the rows. In the *Danainæ* proper, represented by the genus *Ituna*, the transparency is chiefly due to the great diminution in the number of the scales, and those which remain are neither much reduced in size nor altered in shape. In the *Pierinæ*, represented in this group by only a single species, *Dismorphia orise*, the scales are greatly reduced in size, but are neither greatly altered in shape nor diminished in numbers.

Hence in these three sub-families of butterflies transparency is attained in three different ways, viz. (1) by reduction in size and simplification in shape; (2) by reduction in number; and (3) by reduction in size alone.

When we examine the moths which fall into the group, we find a much greater difference in the methods, corresponding to the wider divergence in affinity. In the several species of the genus *Castnia* the scales lose their pigment, although undiminished in size, while they are at the same time set vertically upon the wing, so that light can freely pass between their rows. In the widely separated genus *Hyelosia* the arrangement is nearly the same, except that the vertical scales are much attenuated. In the genus *Anthomyza*, which furnishes the group with many species, the scales retain the normal size, shape, and overlap, but become so completely transparent that the light freely passes through them.

In all the numerous constituents of this large group of Lepidoptera a very close resemblance has been produced by entirely different methods; a result which, it has been argued above, is only consistent with the view that natural selection alone, among all the explanations which have been suggested, has been the cause of the observed phenomena.

I owe to the kindness of Mr. Godman and Mr. Salvin the opportunity of studying all the butterflies of this large transparent-winged group, while Mr.

Herbert Druce kindly lent me those moths which are not represented in the Hope Collection in the Oxford University Museum.

2. *Economic Entomology in the United States.* *By* L. O. Howard, *Ph.D.*

The author described, with some detail, the successive steps in the development of the science of economic entomology in America, and showed that the necessity for work against injurious insects is much greater in America than in Europe. He stated that about sixty persons are now officially engaged in this work in the United States, and that their salaries amount to about 90,000 dollars. Of these sixty persons thirty-three are attached to the State Agricultural Experiment Stations and seventeen to the Department of Agriculture at Washington. A general *résumé* of the character of the work done in these several offices was given, that done in the Department at Washington being described at length.

3. *On some remains of a Sepia-like Cuttle-fish from the Lower Cretaceous rocks of the South Saskatchewan.* *By* J. F. Whiteaves.

In 1889 four rather remarkable fossils, which probably represent the dorsal side of the internal shell, or sepiostaire, of a new species of an apparently new genus closely allied to *Sepia*, were collected by Mr. T. C. Weston, of the Geological Survey of Canada, from the Montana or Pierre-Fox Hills formation of the Later North American Cretaceous at the South Saskatchewan, opposite the mouth of Swift Current Creek.

Each of these fossils is imperfect posteriorily, and not a trace of the mucro is preserved in any of them. The most perfect of the four is about six inches and a quarter in length by about three inches and a quarter in its maximum breadth. It is elliptical or elliptic-ovate in outline, slightly convex, but marked with five narrow, acute, but not very prominent longitudinal ridges, with rather distant faint depressions or shallow grooves between them. One of these ridges is median, but the two lateral ones on each side are slightly divergent, and a bilateral symmetry is very obvious.

A considerable portion of the surface of each of these fossils is obscured by a blackish and apparently bituminous substance, so that it is difficult to trace any of the lines of growth continuously, though they are remarkably well preserved in patches. Near the lateral margins the incremental striæ are simply concentric, but in the median region (where they are fine, extremely numerous and densely crowded) each one is produced anteriorly into an angular and acutely pointed lobe, with its apex upon the summit of the median ridge. From this fact it may be inferred that the anterior margin of the dorsal side of the shell was pointed in the middle when perfect.

So far as the writer has been able to ascertain, there is no known genus of Sepiidæ, fossil or recent, to which these fossils can be satisfactorily referred. They bear, no doubt, a certain general resemblance to the internal shells of *Sepia* itself; but in the sepiostaires of all the recent species of that genus which the writer has been able to examine the radii of the dorsal surface are broad, flattened, and almost obsolete. As already suggested, they seem to indicate a new genus and species of Sepiidæ, for which the name *Actinosepia Canadensis* may not be inappropriate. In any case these specimens, if correctly interpreted, are the first well-marked remains of sepiostaires that have been found in a fossil state in Canada.

4. *The Statistics of Bees.* *By* Professor F. Y. Edgeworth.

Applying to bees one of the methods which he applied to wasps last year, the author has found for the species *Bombus hortorum* that a voyage, from and back to the nest, made in the later afternoon, lasts on an average from thirty to thirty-five minutes. For hive-bees the corresponding length of time appears to be less than ten minutes.

5. *The Appearance of the Army Worm in the Province of Ontario during 1896.* *By* Professor J. HOYES PANTON, *M.A.*

The author gives in this paper the results of his observations upon the army worm (*Leucania unipuncta*) during the summer of 1896, when it appeared in large numbers throughout Ontario. As it infested the fields at the Ontario Agricultural College, he was favourably situated to collect much valuable information.

A sketch accompanying the paper showed very distinctly the infested districts—39 counties and 118 townships. A number of experiments were conducted to ascertain the principal food plants of this insect. The results showed that its food is largely restricted to the *Gramineæ*, and that it will not feed upon plants from the *Leguminosæ* and other orders unless pressed by hunger. When no food was given in twenty-four hours the insects began to devour one another. Many natural enemies were found to prey upon this caterpillar, insectivorous birds, toads, predaceous beetles, and parasitic flies. The Tachina fly (*Nemoræa leucaniæ*) was one of the principal insect foes that kept it in check.

Beneath a windrow of green oats sprinkled with Paris green (a pound to 75 gallons of water) thousands of dead caterpillars lay. This was spread along the ground so as to stop their march into the adjoining field.

Several artificial remedies were referred to, the chief being to plough a furrow with its perpendicular side next the field to be protected, or a ditch may be dug in the same position. Holes dug at intervals of 10 to 15 feet in the furrow or ditch will be useful in catching the worms which fail to climb the sides and wander aimlessly along the furrow. The worms collected in the furrow or ditch may be destroyed as follows:—(*a*) Ploughing a furrow so as to bury them; (*b*) sprinkling coal oil upon them; (*c*) scattering straw over them and firing it; (*d*) dragging a heavy pole along the ditch.

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6. *On a Supposed New Insect Structure.* *By* Professor L. C. MIALL, *F.R.S.*

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7. *On Recapitulation in Development, as illustrated by the Life History of the Masked Crab* (*Corystes*). *By* W. GARSTANG, *M.A.*

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8. *On Musculo-glandular Cells in Annelids.* *By* Professor GUSTAVE GILSON.

TUESDAY, AUGUST 24.

The following Papers were read:—

1. *On the Plankton collected continuously during a traverse of the Atlantic in August* 1897.[1] *By* Professor W. A. HERDMAN, *F.R.S.*

Through the kindness of the owners and of the captain of the Allan liner 'Parisian,' I was enabled to run sea-water through four silk tow-nets of different degrees of fineness continuously day and night during the voyage from Liverpool to Quebec. I used two nets (a coarser inside a finer) on the port side, tied to a tap through which about 3,600 gallons ran in twelve hours. On the starboard side the two nets were attached to an overflow pipe, delivering about 21,600 gallons in the twelve hours—six times as much as on the other side. The nets were emptied and the contents examined morning and evening, so that each gathering was approximately twelve hours' catch, and each day, and each night, of the voyage

[1] This paper will be published in full in the *Transactions* of the Biological Society of Liverpool during the session 1897–98, vol. xii., p. 33.

was represented by a gathering. The water was taken in from the sea about 14 feet below the surface. All the material collected was rapidly examined with the microscope while in the fresh condition, and was then preserved in solutions of formaline or alcohol for future detailed study.

The fauna of the area traversed may, from the preliminary examination of the material, be divided into four sections:—

I. The British Coast fauna—through the Irish Sea and round the north coast of Ireland.

II. The Oceanic North Atlantic fauna, including *Globigerina*, Radiolaria, and other characteristic forms.

III. The Labrador Current fauna, with quantities of large northern Copepoda and Amphipoda.

IV. The North American Coast fauna—somewhat like that of the first section.

[Further details in regard to the characteristic forms in the various gatherings were given at the meeting; but that preliminary account will now be replaced by the fuller description of the material to be published shortly.]

This method of collecting samples of the surface fauna in any required quantity per day or hour from an ocean liner going at full speed was first practised, I believe, by Dr. John Murray, of Edinburgh. The method is simple, effective, and inexpensive. It requires no complicated apparatus, there is no difficulty in the manipulation, and no trouble to speak of need be given to any of the ship's company. It is not even necessary that the naturalist should himself go the voyage. The ship's surgeon or any other officer interested in science can readily carry out the work; and so, at very slight expense, series of gatherings can be obtained across the great oceans in every direction traversed by passenger or cargo steamers.

Addendum.—During the return voyage, at the end of September, the same process was repeated; but in addition to the four nets used previously a fifth was tied periodically over the tap in the bath-room, and the sea-water was allowed to flow through it for stated periods. This gave intermittent gatherings for comparison with those taken continuously. The bath-room gatherings simply showed small samples of the fuller (twelve-hour) day or night gatherings.

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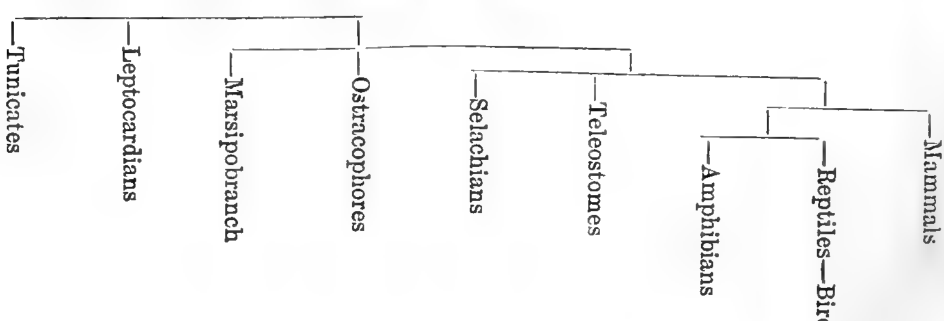
2. *The Determinants for the Major Classification of Fish-like Vertebrates. By* Professor THEODORE GILL.

There is much difference of opinion still respecting the limits of the branch of vertebrates or chordata as well as the classes which compose it. Those which, in the present state of our knowledge, seem to belong to it are the Tunicates, Leptocardians, Marsipobranchs, Ostracophores, Selachians, Teleostomes (Pisces), Amphibians, Reptiles, Birds, and Mammals. The least widely separated of all are the Reptiles and Birds, and if they are retained as distinct classes the others should also be retained. The division into Ichthyopsida, Sauropsida, and Mammalia fails to express the natural relations of the constituent classes. These relations may be exhibited in the following genealogical diagram:—



The gaps between the lower classes are very great. The least differences between the Selachians and Teleostomes are manifest in the Xenacanthini and Dipnoi of the Palæozoic; the least between the Teleostomes and Amphibians in the Crossopterygians and Stegocephals. The differences between the Amphibians and Reptiles are minimised in the Palæozoic. From a generalised stock of the later Palæozoic or earlier Mesozoic the Mammals were doubtless derived.

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3. *On the Derivation of the Pectoral Member in Terrestrial Vertebrates. By* Professor THEODORE GILL.

All attempts at the homologisation of the chiropterygium or anterior limb of the pentadactyle or terrestrial vertebrate with the ichthyopterygium or pectoral fin have been more or less unsatisfactory. The most important hint seems to be furnished by *Polypterus*. Attention was called to the homologies by the author in his Arrangement of the families of Fishes (1872) and the Standard (or Riverside) Natural History. Similar conclusions have since been reached by others. The chief objection to the derivation of the chiropterygium from the pectoral member of such a form as *Polypterus* is that at present no extinct representatives are known. Probably future research will reveal such, as the genus belongs to a very archaic type, and has numerous not very distantly related precursors in the past. The homologies in question are justified by the facts of individual development of the fore-limb in the Reptiles and Mammals.

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4. *The Morphological Significance of the Comparative Study of Cardiac Nerves. By* Dr. W. H. GASKELL, *F.R.S.*

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5. *Observations upon the Morphology of the Cerebral Commissures in the Vertebrata. By* Dr. G. ELLIOT SMITH, *M.A.*

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6. *Some points in the Symmetry of Actinians. By* Professor J. P. MCMURRICH.

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7. *The Natural History of Instinct. By* Professor C. LLOYD MORGAN, *M.A.*

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8. *On the Hæmatozoon Infections in Birds. By* W. G. MACCALLUM, *B.A.*

Several varieties of birds—crows, owls, sparrows, blackbirds, &c.—have been found infected with organisms resembling the malarial organisms of man. These, like the malarial parasites, develop within the red corpuscles, transforming the hæmoglobin into pigment granules. They reproduce by segmentation, although this process does not occur simultaneously for great groups of individuals, so as to make the length of the cycle of development easy of determination, as is the case in the malarial parasites. The young hyaline forms are not actively motile.

Two types of organism are recognised. In one (the Proteosoma of Labbé) the irregularly shaped body is situated at one end of the nucleated red corpuscle, displacing the nucleus toward the opposite end. This form segments in the peripheral circulation. In the other type, which corresponds to the Halteridium of Labbé, the body of the organism is elongated and curved about the nucleus of the corpuscle. Segmenting forms are found in the bone marrow, but not in the circulating blood. There is in this type a certain variation in form in different hosts.

Flagellation is readily observed in both forms, the organism in freshly prepared slides being seen to burst from the corpuscle and almost immediately throw out flagella. Other organisms extruded from the corpuscle degenerate without flagellation.

The tissues of these birds show characteristic changes, resulting from the destruction of blood corpuscles and the deposition of pigment. The spleen and liver are the organs most markedly affected, the pigment being taken up along with infected corpuscles, shrunken parasites, and other *débris* by large makrophages, which probably originate from endothelial cells. These occur in the capillaries and small vessels in these organs. The endothelial cells still attached to the vessel wall are also sometimes swollen and crowded with pigment, &c. In the spleen the large endothelial cells of the pulp bands take on the characters of makrophages. The leucocytes are only exceptionally phagocytic.

The pigment is partly formed by the organisms, partly the result of the breaking down of the hæmoglobin set free in the blood on the rupture of the corpuscle, and there are corresponding variations in its colour.

The other organs, including the bone marrow, are in general very slightly affected. Certain foci of necrosis which occur in various organs have not as yet been definitely associated with the presence of these organisms.

9. *The Post-embryonic Development of* Aspidogaster conchicola. *By* JOSEPH STAFFORD, *Ph.D.*

The author, after mentioning the ways in which this animal differs in form, structure, development, and life history from other Trematodes, and the consequent difficulties in classifying it, gave a brief sketch of the origin of the embryo, and then turned in detail to the life of the young animal after it leaves the egg, during all the time it is undergoing a change in form and developing new organs until it reaches sexual maturity.

Its morphological transformations were represented by eight drawings made to the same scale, and its anatomical structure was represented by a few transverse sections of each stage. The first of these is the just liberated embryo, which now begins to live a free life, and is accordingly, following the suggestion of Brown, called a Miracidium. The lengths of the animal at these different periods are 0·16, 0·33, 0·45, 0·8, 1, 1·2, 1·5 mm. The change in external form was described, and then the origin and change in structure of each organ until it has reached maturity were discussed.

10. *On a particularly large Set of Antlers of the Red Deer* (Cervus elaphus). *By* G. P. HUGHES.

11. *On the Evolution of the Domestic Races of Cattle, with particular Reference to the History of the Durham Short Horn.* *By* G. P. HUGHES.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—J. SCOTT KELTIE, LL.D., SEC.R.G.S.

THURSDAY, AUGUST 19.

The President delivered the following address:—

WE meet this year in exceptional circumstances. Thirteen years ago the British Association met for the first time in a portion of the Empire beyond the limits of the British Islands. During these thirteen years much has happened of the greatest interest to geographers, and if I attempted to review the progress which has been made during these years—progress in the exploration of the globe, progress in geographical research, progress in geographical education—I could not hope to do it to any purpose in the short time during which it would be right for a president to monopolise the attention of the Section. But we have, at the same time, reached another stage in our history which naturally leads us to take stock of our progress in the past. We have all of us been celebrating the 60th year of the glorious reign of the Sovereign, of whose vast dominions Canada and the United Kingdom form integral parts. The progress made during that period in our own department of science has been immense; it would take volumes to tell what has been done for the exploration of the globe. The great continent of Africa has practically been discovered, for sixty years ago almost all but its rim was a blank. In 1837 enormous areas in North America were unexplored, and much of the interior of South America was unknown. In all parts of Asia vast additions have been made to our knowledge; the maps of the interior of that continent were, sixty years ago, of the most diagrammatic character. The Australian interior was nearly as great a blank as that of Africa; New Zealand had not even been annexed. Need I remind you of the great progress which has been made during the period both in the North and South Polar areas, culminating in the magnificent achievement of Dr. Nansen? It was just sixty years ago that the great Antarctic expedition under Sir James Ross was being organised; since that, alas, little or nothing has been done to follow up his work. Sixty years ago the science of Oceanography, even the term, did not exist; it is the creation of the Victorian era, and may be said almost to have had its origin in the voyage of the 'Challenger,' which added a new domain to our science and opened up inexhaustible fields of research. I have thought then that the most useful and most manageable thing to do on the present occasion will be to indicate briefly what, in my estimation, are some of the problems which geography has to attack in the future, only taking such glances at the past as will enable us to do this intelligibly.

It has been customary for the occupants of this chair to try to define the field of geography, and on occasions, in somewhat too apologetic language, to justify its existence as a section of a scientific association. I do not think this is

any longer necessary. Even in England and America, during the last thirteen years, geography has done work enough to prove that she has a mission which no other department of research can fulfil. I say thirteen years, because that not only carries us back to the last Canadian meeting of the British Association, but to the year when the Royal Geographical Society undertook an inquiry into the position of geography at home and abroad, mainly with a view to the improvement of geographical education in England. During that time a good deal has been written as to the field and scope of geography, and a good many definitions given. But we really did not require to go to Germany to teach us as to the field and functions of geography. Sixty years ago, the then President of the Royal Geographical Society, Mr. William R. Hamilton, delivered the first presidential address ever given at that Society, and his conception of the field and aims of geography was as exalted and comprehensive as the most exacting German geographer could wish. It is too long to quote here.[1]

It would be difficult to improve upon Mr. Hamilton's definition, and it shows that a correct conception of the wide and important field of geography is no new thing in England. He proceeded to indicate what remained to be done in the field of exploration, and I commend his address to anyone desirous of forming a conception of the vast progress that has been made since it was delivered, sixty years ago. Since I am dealing with definitions, I may be permitted to quote that given by one so severely scientific as General Sir R. Strachey in a course of lectures which he gave at the University of Cambridge in 1888, in connection with the establishment of a lecturership in Geography in that University. 'The aim of geographical science,' he says, 'is to investigate and delineate the various features of the earth; to study the distribution of land and sea, the configuration and relief of the surface, position on the globe, and so forth, facts which determine the existing condition of various parts of the earth, or which indicate former conditions; and to ascertain the relations that exist between these features and all that is observed on the earth. . . . I claim for geography,' Sir R. Strachey says, 'a place among the natural sciences as supplying the needful medium through which to obtain a connected and consistent conception of the earth and what is on it.' He gives a list of the various matters which, in his conception, it is the business of geography to deal with, and they are varied and important enough to satisfy the demands of the most exacting. 'These are,' he says, 'the studies through which scientific geography will lead you, teaching you to view the earth in its entirety, bringing together the great variety of objects seen upon it, investigating their connection, and exploring their causes; and so combining and harmonising the lessons of all the sciences which supply the key to the secrets of Nature.'[2]

I think we may briefly define geography as the science of the topographical distribution of the great features of the earth's surface and of all that it sustains—mineral, vegetable, and animal, including man himself. In fact, man is the ultimate term in the geographical problem, the final object of which is to investigate the correlation between humanity and its geographical environment.

I may be pardoned for dwelling at some length on the function and field of geography. It is a subject that has been occupying the attention of geographers in England for some years, and it may not be without interest to our colleagues on this side of the Atlantic to know the conclusions which we have come to. Moreover, it seems necessary to arrive at some clear conception on the matter, with a view to the researches of the future. I say that the subject has been occupying our attention in England for some time; it has done so, I may say, as a result of the inquiry by myself on the part of the Royal Geographical Society to which I have referred. The object of that inquiry was mainly to collect information as to the position of geography in education at home and abroad. The report which I presented to the Society attracted some attention, and whether as

[1] *Journal R.G.S.* vol. viii. 1838.

[2] 'Lectures on Geography delivered before the University of Cambridge.' London, 1888.

a result of that or not it is hardly for me to say, but certainly since that inquiry some twelve years ago the position of geography in England has considerably improved both in education and as a field for research. Better methods have been introduced in our schools; a much wider scope has been given to the subject; in many quarters teachers have shown themselves anxious to be guided in the right direction; and, above all, both Oxford and Cambridge at length consented to the establishment of lectureships in geography. A school of young geographers has grown up, consisting of men who have had a thorough university training in science and letters, and who are devoting themselves to the various branches of geography as a speciality. In this way the arid old text-books and characterless maps are being supplanted by others that will bear comparison with the best productions of Germany. Photography and lantern slides illustrating special geographical features are coming into use in schools; and in other directions appliances for use in education are being multiplied and improved. A British geographical literature is growing up, and if, as I hope, the progress be maintained, we shall be able to hold our own in geography with any country. The interest in the subject has been extended by the foundation of geographical societies in various large centres; whereas thirteen years ago the only geographical society was that of London, there are now similar societies in Manchester, Newcastle, Liverpool, and Edinburgh, the last with branches in Glasgow, Dundee, and Aberdeen. If this progressive movement is maintained, as there is every reason to hope it will be, the scientific and educational aspects of geography in Britain will be more nearly on a par with exploration in which our country has so long held the lead.

In the United States I found that the position of the subject in education was not much more satisfactory than it was in England. Since then there is reason to believe considerable progress has been made. One of the best text-books on physical geography, Hinman's 'Eclectic Physical Geography,' is of American origin; while in the States, as in England, a school of scientific geographers has arisen which bids fair to give the subject a high place in that country. I fear, from what I can learn, that the position in Canada is not as satisfactory as it ought to be. It seems to me, then, that one of the great problems which geographers have to face in the future is the place which this subject is to hold in education, both as a body of information and as a discipline. We have been making progress, and if we persevere with intelligence and firmness, and maintain the subject at the highest standard as a field of research, there can be little doubt of our success.

There is a prevalent belief that geographers have nothing more to learn in Europe, that that old continent has been thoroughly explored. It is true that nearly every country in Europe has been, or is being, trigonometrically surveyed. Except some parts of the Balkan Peninsula and North of Russia, the topography of the continent has been accurately mapped on scales and by methods sufficient at least for the purposes of the geographer. Yet there are districts in the Balkan Peninsula—for example, Albania—which are as vaguely known as Central Africa. But it is a delusion to think that because a country has been fully mapped the occupation of the geographer is gone. It is only when a region at large is adequately mapped that the work of geographical research begins. The student, with a satisfactory map of a definite district as his guide, will find on the spot abundant occupation in working out its geographical details, the changes which have taken place in its topography, and the bearing of its varied features upon its history, its inhabitants, its industries. This kind of work has been in progress in Germany for over ten years, under the auspices of the Central Commission for the Scientific Geography (Landeskunde) of Germany, with its seat at Stuttgart. Under the collective title of 'Forschungen zur Deutschen Landes- und Volkskunde,' a long series of monographs by specialists has been published, dealing in minute detail with one or more aspects of a limited district. Thus we have such memoirs as 'The Plain of the Upper Rhine and its Neighbouring Mountains,' by Dr. Richard Lepsius; 'The Towns of the North German Plain in relation to the Configuration of the Ground,' by Dr. Hahn; 'The Munich Basin: a Contribution to the Physical Geography of Southern Bavaria,' by C. Gruber; 'The Mecklenburg Ridges and their Relation to the Ice Age,' by Dr. E. Geinitz; 'The Influence of the Mountains on the

Climate of Central Germany,' by R. Assmann; 'The Distribution and Origin of the Germans in Silesia,' by Dr. K. Weinhold; 'Mountain Structure and Surface Configuration of Saxon Switzerland,' by Dr. A. Hettner; 'The Erzgebirge: an Orometric-Anthropogeographical Study,' by Dr. J. Burgkhardt; 'The Thuringian Forest and its Surroundings,' by Dr. H. Pröscholdt, and so forth. There is thus an inexhaustible field for scientific geography in its most comprehensive sense, a series of problems which may take generations to work out. In a less systematic way we have similar monographs by French geographers. One or two attempts, mainly by teachers, have been made in England to do similar work, but the impression generally produced is that the authors have not been well equipped for the task. I am glad to say that in England the Royal Geographical Society has initiated a movement for working out in a systematic fashion what one may call the regional geography of the British Islands on the basis of the one-inch maps of the Ordnance Survey. It is a strange thing that the geography of the Mother Country has never yet been systematically worked out.

Taking the sheets of the Ordnance Survey map as a basis, it is proposed that each district should be thoroughly investigated, and a complete memoir of moderate dimensions systematically compiled to accompany the sheet, in the same way that each sheet of the Geological Survey map has its printed text. It is a stupendous undertaking that would involve many years' work, and the results of which when complete would fill many volumes. But it is worth doing; it would furnish the material for an exact and trustworthy account of the geography of Britain on any scale, and would be invaluable to the historian, as well as to others dealing with subjects having any relation to the past and present geography of the land. The librarian of the Society, Dr. H. R. Mill, has begun operations on a limited area in Sussex. When he has completed this initial memoir, it will be for the Society to decide whether it can continue the enterprise, or whether it will succeed in persuading the Government to take the matter up. I refer to work of this kind mainly to indicate what, in my conception, are some of the problems of the future which geography has to face, even in fully surveyed countries. Even were the enterprise referred to carried out, there would be room enough for special researches in particular districts.

But while there is an inexhaustible field in the future for geographical work in the direction I have indicated, there is no doubt that much still remains to be done in the way of exploring the unknown, or little known, regions of the globe. Let us briefly refer to the problems remaining to be solved in this direction. Turning to the continent of Asia, we find that immense progress has been made during the past sixty years. In the presidential address given sixty years ago, already referred to, Mr. Hamilton says of Asia:—'We have only a very general knowledge of the geographical character of the Burman, Chinese, and Japan empires; the innumerable islands of the latter are still, except occasionally, inaccessible to European navigators. Geographers hardly venture on the most loose description of Tibet, Mongolia, or Chinese Tartary, Siam, and Cochin China.' Since then the survey of India, one of the greatest enterprises undertaken by any State, has been completed, and is being rapidly extended over Burma. But I need not remind you in detail of the vast changes that have taken place in Asia during these years, and the immense additions that have been made to our knowledge of its geography. Exploring activity in Asia is not likely to cease, though it is not to be expected that its inhospitable centre will ever be so carefully mapped as have been the mountains of Switzerland.

The most important desiderata, so far as pioneer exploration in Asia is concerned, may be said to be confined to two regions.[1] In Southern and Central Arabia there are tracts which are entirely unexplored. It is probable that this unexplored region is in the main a sandy desert. At the same time it is, in the south at least, fringed by a border of mountains whose slopes are capable of rich cultivation, and whose summits the late Mr. Theodore Bent found, on his last and

[1] For part of what follows with reference to Asia, I am indebted to a valuable Memorandum on the subject drawn up by the late Mr. Ney Elias.

fatal journey, to be covered with snow. In exploration, as in other directions, it is the unexpected that happens; and if any traveller cared to face the difficulties—physical, political, and religious—which might be met with in Southern and Central Arabia, he might be able to tell the world a surprising story.

The other region in Asia where real pioneer work still remains to be done is Tibet and the mountainous districts bordering it on the north and east. Lines of exploration have in recent years been run across Tibet by Russian explorers like Prejevalsky, by Rockhill, Prince Henry of Orleans and Bonvalot, by Bower, Littledale, Wellby, and Malcolm. From the results obtained by these explorers we have formed a fair idea of this, the most extensive, the highest, and the most inhospitable plateau in the world. A few more lines run in well-selected directions would probably supply geography with nearly all she wants to learn about such a region, though more minute exploration would probably furnish interesting details as to its geological history.

The region lying to the north of the Himalayan range and to the south of the parallel of Lhasa is almost a blank on the map, and there is ample room here for the enterprising pioneer. The forbidden city of Lhasa is at present the goal of several adventurers, though as a matter of fact we cannot have much to learn in addition to what has been revealed in the interesting narrative of the native Indian traveller, Chandra Das. The magnificent mountain region on the north and east of Tibet furnishes a splendid field for the enterprising explorer. Mrs. Bishop recently approached it from the east, through Sze-chuen, and her description of the romantic scenery and the interesting non-Mongolian inhabitants leaves us with a strong desire to learn more. On the south-east of Tibet is the remarkable mountainous region, consisting of a series of lofty parallel chains, through which run the upper waters of the Yangtse, the Mekong, the Salwin, and the Irawady. This last-named river, recent exploration has shown, probably does not reach far into the range. But it will be seen by a glance at a map that the upper waters of the other rivers are carried far into the heart of the mountains. But these upper river courses are entirely conjectural and have given rise to much controversy. There is plenty of work here for the explorer, though the difficulties, physical and political, are great.

But besides these great unexplored regions, there are many blanks to be filled up in other parts of Asia, and regions which, though known in a general way, would well repay careful examination. There is the mountain track between the upper Zarafshan river and the middle course of the Sarkhab tributary of the Oxus, and the country lying between that and the Oxus. There is the great Takla-Makan desert in Chinese or Eastern Turkistan, part of which has recently been explored by Russian expeditions and by that young and indefatigable Swedish traveller, Dr. Sven Hedin. It is now one of the most forbidding deserts to be found anywhere, but it deserves careful examination, as there are evidences of its once having been inhabited, and that at no very remote period. It is almost surrounded by the Tarim, and on its eastern edge lies Lob-nor, the remarkable changes in which have been the subject of recent investigation. As readers of Dr. Nansen's 'Voyage of the Fram' will remember, the Siberian Coast is most imperfectly mapped; of course, it is a difficult task, but it is one to which the Russian Government ought to be equal. China has on paper the appearance of being fairly well mapped; but as a matter of fact our knowledge of its mountain ranges and of its great river courses is to a large extent extremely vague. All this awaits careful survey. In North-eastern Manchuria and in many parts of Mongolia there are still blanks to be filled up and mountain and river systems to be surveyed. In the Malay Peninsula and in the great array of islands in the east and south-east of Asia—Sumatra, Borneo, the Philippines—much work still remains to be done. Thus for the coming century there will be abundance of work for explorers in Asia, and plenty of material to occupy the attention of our geographical societies.

Coming to the map of Africa, we find the most marvellous transformation during the last sixty years, and mainly during the last forty years, dating from Livingstone's memorable journey across the continent. Though the north of Africa

was the home of one of the oldest civilisations, and though on the shores of the Mediterranean, Phœnicians, Carthaginians, Greeks, and Romans were at work for centuries, it has only been within the memory of many of us that the centre of the continent, from the Sahara to the confines of Cape Colony, has ceased to be an unexplored blank. This blank has been filled up with bewildering rapidity. Great rivers and lakes and mountains have been laid down in their main features, and the whole continent, with a few unimportant exceptions, has been parcelled out among the Powers of Europe. But much still remains to be done ere we can form an adequate conception of what is in some respects the most interesting and the most intractable of the continents. Many curious problems still remain to be solved. The pioneer work of exploration has to a large extent been accomplished; lines have been run in all directions; the main features have been blocked out. But between these lines the broad meshes remain to be filled in, and to do this will require many years of careful exploration. However, there still remain one or two regions that afford scope for the adventurous pioneer.

To the south of Abyssinia and to the west and north-west of Lake Rudolf, on to the Upper Nile, is a region of considerable extent, which is still practically unknown. Again, in the Western Sahara there is an extensive area, inhabited mainly by the intractable Tuaregs, into which no one has been able to penetrate, and of which our knowledge is extremely scanty. Even in the Central Sahara there are great areas which have not been traversed, while in the Libyan desert much remains to be done. These regions are of interest almost solely from the geographical and geological standpoints. But they deserve careful investigation, not only that we may ascertain their actual present condition, but in order, also, that we may try to discover some clues to the past history of this interesting continent. Still, it must be said that the great features of the continent have been so fully mapped during the last half century that what is required now is mainly the filling-in of the details. This is a process that requires many hands and special qualifications. All over the continent there are regions which will repay special investigation. Quite recently an English traveller, Mr. Cowper, found not far from the Tripoli coast miles of magnificent ruins and much to correct on our maps. If only the obstructiveness of the Turkish officials could be overcome, there is a rich harvest for anyone who will go to work with patience and intelligence. Even the interior of Morocco, and especially the Atlas Mountains, are but little known. The French, both in Tunis and Algeria, are extending our knowledge southwards. All the Powers who have taken part in the scramble for Africa are doing much to acquire a knowledge of their territories. Germany, especially, deserves praise for the persistent zeal with which she has carried out the exploration of her immense territories in East and West Africa. The men she sends out are unusually well qualified for the work, capable not simply of making a running survey as they proceed, and taking notes on country and people, but of rendering a substantial account of the geology, the fauna, the flora, and the economic conditions. Both in the French and the British spheres good work is also being done, and the map of Africa being gradually filled up. But what we especially want now are men of the type of Dr. J. W. Gregory, whose book on the Great Rift Valley is one of the most valuable contributions to African geography ever made. If men of this stamp would settle down in regions like that of Mount Ruwenzori, or Lake Rudolf, or the region about Lakes Bangweolo and Tanganyika, or in the Atlas, or in many other regions that could be named, the gains to scientific geography, as well as to the economical interests of Africa, would be great. An example of work of this kind is seen in the discoveries made by a young biologist trained in geographical observation, Mr. Moore, on Lake Tanganyika. There he found a fauna which seems to afford a key to the past history of the centre of the continent, a fauna which, Mr. Moore maintains, is essentially of a salt-water type. Mr. Moore, I believe, is inclined to maintain that the ancient connection of this part of Africa with the ocean was not by the west, as Joseph Thomson surmised, but by the north, through the Great Rift Valley of Dr. Gregory; and he strongly advocates the careful examination of Lake Rudolf as the crucial test of his theory. It is to be hoped that he, or someone equally competent, will have an opportunity

of carrying out an investigation likely to provide results of the highest importance.

But there are other special problems connected with this, the most backward and the most repellent of continents, which demand serious investigation, problems essentially geographical. One of the most important of these, from the point of view of the development of Africa, is the problem of acclimatisation. The matter is of such prime importance that a committee of the Association has been at work for some years collecting data as to the climate of Tropical Africa. In a general way we know that that climate is hot and the rainfall scanty; indeed, even the geographers of the Ancient World believed that Central Africa was uninhabitable on account of its heat. But science requires more than generalities, and therefore we look forward to the exact results which are being collected by the Committee referred to with much hope. We can only go to work experimentally until we know precisely what we have to deal with. It will help us greatly to solve the problem of acclimatisation when we have the exact factors that go to constitute the climate of Tropical Africa. At present there is no doubt that the weight of competent opinion—that is, the opinion of those who have had actual experience of African climate, and of those who have made a special study of the effects of that climate on the human constitution—is that though white men, if they take due precautions, may live and do certain kinds of work in Tropical Africa, it will never be possible to colonise that part of the world with people from the temperate zone. This is the lesson taught by generations of experience of Europeans in India. So far, also, sad experience has shown that white people cannot hope to settle in Central Africa as they have settled in Canada and the United States and in Australia, and make it a nursery and a home for new generations. Even in such favourable situations as Blantyre, a lofty region on the south of Lake Nyasa, children cannot be reared beyond a certain age; they must be sent home to England, otherwise they will degenerate physically and morally. No country can ever become the true home of a people if the children have to be sent away to be reared. Still, it is true our experience in Africa is limited. It has been maintained that it might be possible to adapt Europeans to Tropical Africa by a gradual process of migration. Transplant Southern Europeans to North Africa; after a generation or two remove their progeny further south, and so on, edging the succeeding generation further and further into the heart of the continent. The experiment—a long one it would be—might be tried; but it is to be feared that the ultimate result would be a race deprived of all those characteristics which have made Europe what it is. An able young Italian physician, Dr. Sambon, has recently faced this important problem, and has not hesitated to come to conclusions quite opposed to those generally accepted. His position is that it has taken us centuries in Europe to discover our hidden enemies, the microbes of the various diseases to which Northern humanity is a prey, and to meet them and conquer them. In Africa we have a totally different set of enemies to meet, from lions and snakes down to the invisible organisms that produce those forms of malaria, anæmia, and other diseases characteristic of tropical countries. He admits that these are more or less due to heat, to the nature of the soil, and other tropical conditions, but that if once we knew their precise nature and modes of working we should be in a position to meet them and conquer them. It may be so, but this is a result that could only be reached after generations of experience and investigation; and even Dr. Sambon admits that the ultimate product of European acclimatisation in Africa would be something quite different from the European progenitors. What is wanted is a series of carefully-conducted experiments. I have referred to the Blantyre highlands; in British East Africa there are plateaus of much greater altitude, and in other parts of Central Africa there are large areas of 4,000 feet and over above sea-level. The world may become so full that we may be forced to try to utilise these lofty tropical regions as homes for white people when Canada and Australia and the United States become over-populated. As one of my predecessors in this chair (Mr. Ravenstein) tried to show at the Leeds Meeting some years ago, the population of the world will have more than doubled in a century, and about 180 years hence will have quadrupled. At any rate,

here is a problem of prime importance for the geographer of the coming century to attack; with so many energetic and intelligent white men all over Africa, it should not be difficult to obtain the data which might help towards its solution.

I have dwelt thus long on Africa, because it will really be one of the great geographical problems of the coming century. Had it been as suitable as America or Australia, we may be sure it would not have remained so long neglected and despised by the European peoples as it has done. Unfortunately for Africa, just as it had been circumnavigated, and just as Europeans were beginning to settle upon its central portion and trying to make their way into the interior, Columbus and Cabot discovered a new world, a world as well adapted as Europe for the energies of the white races. That discovery postponed the legitimate development of Africa for four centuries. Nothing could be more marked than the progress which America has made since its re-discovery 400 years ago, and the stagnation of Africa which has been known to Europe since long before the beginning of history. During these 400 years North America at least has been very thoroughly explored. The two great nations which divide North America between them have their Government surveys, which are rapidly mapping the whole continent and investigating its geology, physical geography, and its natural resources. I need hardly tell an audience like this of the admirable work done by the Survey of Canada under Sir William Logan, Dr. Selwyn, and his successor, Dr. George Dawson; nor should it be forgotten that under the Lands Department much excellent topographical work has been carried out by Captain Deville and his predecessors. Still, though much has been done, much remains to be done. There are large areas which have not as yet even been roughly mapped. Within quite recent years we have had new regions opened up to us by the work of Dawson and Ogilvie on the Yukon, by Dr. Bell in the region to the south of Hudson's Bay, by the brothers Tyrrell in the Barren Lands on the west of the same bay, by O'Sullivan beyond the sources of the Ottawa, and by Low in Labrador. But it is not so long since that Dr. Dawson, in reviewing what remains to be done in the Dominion in the way of even pioneer exploration, pointed out that something like a million square miles still remained to be mapped. Apart from the uninhabitable regions in the north, there are, as Dr. Dawson pointed out, considerable areas which might be turned to profitable agricultural and mining account of which we know little, such areas as these which have been recently mapped on the south of Hudson's Bay by Dr. Bell, and beyond the Ottawa by Mr. O'Sullivan. Although the Eastern and the Western Provinces have been very fully surveyed, there is a considerable area between the two lying between Lake Superior and Hudson's Bay which seems to have been so far almost untouched. A very great deal has been done for the survey of the rivers and lakes of Canada. I need hardly say that in Canada, as elsewhere in America, there is ample scope for the study of many problems in physical geography—past and present glaciation and the work of glaciers, the origin and régime of lake basins, the erosion of river-beds, the oscillation of coast-lines. Happily, both in Canada and the United States there are many men competent and eager to work out problems of this class, and in the Reports of the various surveys, the Transactions of American learned Societies, in scientific periodicals, in separate publications, a wealth of data has already been accumulated of immense value to the geographer.

Every geologist and geographer knows the important work which has been accomplished by the various surveys of the United States, as well as by the various State Surveys. The United States Coast Survey has been at work for more than half a century, mapping not only the coast but all the navigable rivers. The Lake Survey has been doing a similar service for the shores of the great lakes of North America. But it is the work of the Geological Survey which is best known to geographers—a survey which is really topographical as well as geological, and which, under such men as Hayden, King, and Powell, has produced a series of magnificent maps, diagrams and memoirs, of the highest scientific value and interest. Recently this survey has been placed on a more systematic basis; so that now a scheme for the topographical survey of the whole of the territory of the United States is being carried out. Extensive areas in various parts of the States have been already surveyed on different scales. It is to be hoped that in the future,

as in the past, the able men who are employed on this survey work will have opportunities of working out the physiography of particular districts, the past and present geography of which is of advancing scientific interest. Of the complete exploration and mapping of the North American continent we need have no apprehension; it is only a question of time, and it is to be hoped that neither of the Governments responsible will allow political exigencies to interfere with what is really a work of national importance.

It is when we come to Central and South America that we find ample room for the unofficial explorer.[1] In Mexico and the Central American States there are considerable areas of which we have little or only the vaguest knowledge. In South America there is really more room now for the pioneer explorer than there is in Central Africa. In recent years the Argentine Republic has shown a laudable zeal in exploring and mapping its immense territories, while a certain amount of good work has also been done by Brazil and Chili. Most of our knowledge of South America is due to the enterprise of European and North American explorers. Along the great river courses our knowledge is fairly satisfactory, but the immense areas, often densely clad with forests, lying between the rivers are almost entirely unknown. In Patagonia, though a good deal has recently been done by the Argentine Government, still in the country between Punta Arenas and the Rio Negro, we have much to learn; while on the west coast range, with its innumerable fjord-like inlets, its islands and peninsulas, there is a fine field for the geologist and physical geographer. Indeed, throughout the whole range of the Andes systematic exploration is wanted, exploration of the character of the excellent work accomplished by Whymper in the region around Chimborazo There is an enormous area lying to the east of the Northern Andes, and including their eastern slopes, embracing the eastern half of Ecuador and Colombia, Southern Venezuela, and much of the country lying between that and Northern Bolivia, including many of the upper tributaries of the Amazon and Orinoko, of which our knowledge is of the scantiest. Even the country lying between the Rio Negro and the Atlantic is but little known. There are other great areas, in Brazil and in the Northern Chaco, which have only been partially described, such as the region whence the streams forming the Tapajos and the Paraguay take their rise, in Mato Grosso. A survey and detailed geographical and topographical description of the whole basin of Lake Titicaca is a desideratum. In short, in South America there is a wider and richer field for exploration than in any other continent. But no mere rush through these little-known regions will suffice. The explorer must be able not only to use his sextant and his theodolite, his compass, and his chronometer. Any expeditions entering these regions ought to be able to bring back satisfactory information on the geology of the country traversed, and of its fauna and flora, past and present; already the revelations which have been made of the past geography of South America, and of the life that flourished there in former epochs, are of the highest interest. Moreover, we have here the remains of extinct civilisations to deal with, and although much has been done in this direction, much remains to be done, and in the extensive region already referred to, the physique, the traditions, and the customs of the natives will repay careful investigation.

The southern continent of Australia is in the hands of men of the same origin as those who have developed to such a wonderful extent the resources of Canada and the United States, and therefore we look for equally satisfactory results so far as the characteristics of that continent permit. The five colonies which divide among them the three million square miles of the continent have each of them efficient Government surveys, which are rapidly mapping their features and investigating their geology. But Australia has a trying economic problem to solve. In none of the Colonies is the water-supply quite adequate; in all are stretches of desert country of greater or less extent. The centre and western half of the continent is covered by a desert more waterless and more repellent than even the Sahara; so

[1] I am indebted for much of the information relative to South America to a valuable Memorandum by Sir Clements R. Markham and Colonel G. E. Church.

far as our present knowledge goes one-third of the continent is uninhabitable. This desert area has been crossed by explorers, at the expense of great sufferings, in various directions, each with the same dreary tale of almost featureless sandy desert, covered here and there with Spinifex and scrub, worse than useless. There are hundreds of thousands of square miles still unknown, but there is no reason to believe that these areas possess any features that differ essentially from those which have been found along the routes that have been explored. There have been one or two well-equipped scientific expeditions in recent years that have collected valuable data with regard to the physical characteristics, the geology and biology of the continent; and it is in this direction that geography should look for the richest results in the future. There remains much to be done before we can arrive at satisfactory conclusions as to the physical history of what is in some respects the most remarkable land area on the globe. Though the surface water supply is so scanty there is reason to believe that underneath the surface there is an immense store of water. In one or two places in Australia, especially in Western Queensland, and in New South Wales, this supply has been tapped with satisfactory results; millions of gallons a day have been obtained by sinking wells. Whether irrigation can ever be introduced on an extensive scale into Australia depends upon the extent and accessibility of the underground water-supply, and that is one of the geographical problems of the future in Australia. New Zealand has been fairly well surveyed, though a good deal remains to be done before its magnificent mountain and glacier system is completely known. In the great island of New Guinea both the British and the Germans are opening up the interiors of their territories to our knowledge, but the western and much larger portion of the island presents a large field for any explorer who cares to venture into its interior.

The marvellous success which has attended Dr. Nansen's daring adventure into the Arctic seas has revived a widespread interest in Polar exploration. Nansen may be said to have almost solved the North Polar problem—so far, at least, as the Old World side of the Pole is concerned. That some one will reach the Pole at no distant date is certain; Nansen has shown the way, and the legitimate curiosity of humanity will not rest satisfied till the goal be reached. But Arctic exploration does not end with the attainment of the Pole. Europe has done her share on her own side of the Pole; what about the side which forms the Hinterland of North America, and specially of Canada? To the north of Europe and Asia we have the scattered groups of islands Spitsbergen, Franz Josef Land, Novaya Zemlya, and the New Siberian Islands. To the north of America we have an immense archipelago, the actual extent of which is unknown. Nansen and other Arctic authorities maintain that the next thing to be done is to complete exploration on the American side, to attempt to do for that half of the North Polar region what Nansen has done for the other half. It may be that the islands which fringe the northern shores of the New World are continued far to the north; if so they would form convenient stages for the work of a well-equipped expedition. It may be that they do not go much farther than we find them on our maps. Whatever be the case it is important, in the interests of science, that this section of the Polar area be examined; that as high a latitude as possible be attained; that soundings be made to discover whether the deep ocean extends all round the Pole. It is stated that the gallant Lieutenant Peary has organised a scheme of exploring this area which would take several years to accomplish. Let us hope that he will be able to carry out his scheme. Meantime, should Canada look on with indifference? She has attained the standing of a great and prosperous nation. She has shown the most commendable zeal in the exploration of her own immense territory. She has her educational, scientific, and literary institutions which will compare favourably with those of other countries; her Press is of a high order, and she has made the beginnings of a literature and an art of her own. In these respects she is walking in the steps of the Mother Country. But has Canada not reached a stage when she is in a position to follow the maternal example still further? What has more contributed to render the name

of Great Britain illustrious than those great enterprises which for centuries she has sent out from her own shores, not a few of them solely in the interests of science? Such enterprises elevate a nation and form its glory and its pride. Surely Canada has ambitions beyond mere material prosperity, and what better beginning could be made than the equipment of an expedition for the exploration of the seas that lie between her and the Pole? I venture to throw out these suggestions for the consideration of those who have at heart the honour and glory of the great Canadian Dominion.

Not only has an interest in Arctic exploration been revived, but in Europe at least an even greater interest has grown up in the exploration of the region around the opposite pole of the earth of which our knowledge is so scanty. Since Sir James C. Ross's expedition, which was sent out in the year 1839, almost nothing has been done for Antarctic research. We have here to deal with conditions different from those which surround the North Pole. Instead of an almost landless ocean, it is believed by those who have given special attention to the subject that a continent about the size of Australia covers the south polar region. But we don't know for certain, and surely, in the interests of our science, it is time we had a fairly adequate idea of what are the real conditions. We want to know what is the extent of that land, what are its glacial conditions, what is the character of its geology, what evidence exists as to its physical and biological conditions in past ages? We know there is one lofty, active volcano; are there any others? Moreover, the science of terrestrial magnetism is seriously impeded in its progress because the data in this department from the Antarctic are so scanty. The seas around this continent require to be investigated both as to their depth, their temperature, and their life. We have here, in short, the most extensive unexplored area on the surface of the globe. For the last three or four years the Royal Geographical Society, backed by other British societies, have been attempting to move the Home Government to equip an adequate expedition to complete the work begun by Ross sixty years ago, and to supplement the great work of the 'Challenger.' But though sympathy has been expressed for Antarctic exploration, and though vague promises have been given of support, the Government is afraid to enter upon an enterprise which might involve the services of a few naval officers and men. We need not criticise this attitude. But the Royal Geographical Society has determined not to let the matter rest here. It is now seeking to obtain the support of public-spirited men for an Antarctic expedition under its own auspices. It is felt that Antarctic exploration is peculiarly the work of England, and that if an expedition is undertaken, it will receive substantial support from the great Australasian Colonies, which have so much to gain from a knowledge of the physical condition of a region lying at their own doors, and probably having a serious influence on their climatological conditions. Here, then, is one of the greatest geographical problems of the future, the solution of which should be entered upon without further delay. It may be mentioned that a small and well-equipped Belgian expedition has already started, mainly to carry out deep-sea research around the South Polar area, and that strenuous efforts are being made in Germany to obtain the funds for an expedition on a much larger scale.

But our science has to deal not only with the lands of the globe; its sphere is the whole of the surface of the earth, and all that is thereon, so far at least as distribution is concerned. The department of Oceanography is a comparatively new creation; indeed, it may be said to have come definitely into being with the famous voyage of the 'Challenger.' There had been expeditions for ocean investigation before that, but on a very limited scale. It has only been through the results obtained by the 'Challenger,' supplemented by those of expeditions that have examined more limited areas, that we have been able to obtain an approximate conception of the conditions which prevail throughout the various ocean depths—conditions of movement, of temperature, of salinity, of life. We have only a general idea of the contours of the ocean-bed, and of the composition of the sediment which covers that bed. The extent of the knowledge thus acquired may be gauged from the fact that it occupies a considerable space in the fifty quarto volumes—the 'Challenger Publications'—which it took Dr. John Murray twenty years to bring out. But

that great undertaking has only, as it were, laid down the general features of the oceanic world. There is plenty of room for further research in this direction. Our own surveying ships, which are constantly at work all over the world, do a certain amount of oceanic work, apart from mere surveying of coasts, and islands, and shoals. In 1895 one of these found in the South Pacific soundings deeper by 500 fathoms than the deepest on record, that found twenty years earlier by the 'Tuscarora' to the north-east of Japan. The deepest of these new soundings was 5,155 fathoms. In the interests of science, as well as of cable-laying, it is desirable that our surveying ships should be encouraged to carry out work of this kind more systematically than they do at present. This could surely be arranged without interfering with their regular work. We want many more observations than we now have, not only on ocean depths, but on the nature of the ocean-bed, before we can have a satisfactory map of this hidden portion of the earth's surface, and form satisfactory conclusions as to the past relations of the ocean-bed with what is now dry land. I believe the position maintained by geologists, that from the remote period when the great folds of the earth were formed the present relations between the great land-masses and the great oceans have been essentially the same; that there have no doubt been great changes, but that these have been within such limits as not to materially affect their relations as a whole. This is a problem which further oceanic research would go a long way to elucidate. That striking changes are going on at the present day, and have been going on within the human period, cannot be doubted. Some coast-lines are rising; others are falling. Professor John Milne, our great authority on Seismology, has collected an extremely interesting series of data, as to the curious changes that have taken place in the ocean-bed since telegraphic cables have been laid down. The frequent breakages of cables have led to the examination of the sub-oceanic ground on which they have been laid, and it is found that slides and sinkings have occurred, in some cases amounting to hundreds of fathoms. These, it is important to note, are on the slopes of the Continental Margin, or, as it is called, the Continental Shelf, as, for example, off the coast of Chili. It is there, where the earth's crust is peculiarly in a state of unstable equilibrium, that we might expect to find such movements; and therefore soundings along the Continental Margins, at intervals of say five years, might furnish science with data that might be turned to good account.

As an example of what may be done by a single individual to elucidate the present and past relations between land and sea, may I refer to an able paper in the 'Geographical Journal' of May, 1897, by Mr. T. P. Gulliver, a pupil of Professor Davis, of Harvard, himself one of the foremost of our scientific geographers? Mr. Gulliver has made a special study on the spot, and with the help of good topographical and geological maps, of Dungeness Foreland on the south-east coast of Kent. Mr. Gulliver takes this for his subject, and works out with great care the history of the changing coast-line here, and in connection with that the origin and changes of the English Channel. This is the kind of work that well-trained geographical students might undertake. It is work to be encouraged, not only for the results to be obtained, but as one species of practical geographical training in the field, and as a reply to those who maintain that geography is mere book-work, and has no problems to solve. Professor Davis himself has given an example of similar practical work in his elaborate paper on 'The Development of Certain English Rivers' in the 'Geographical Journal' for February, 1895 (vol. v. p. 127), and in many other publications.

Another important problem to attack, and that in the near future, is that of Oceanic Islands. I say in the near future, because it is to be feared that very few islands now remain unmodified by contact with Europeans. Not only have the natives been affected, both in physique and in customs, but the introduction of European plants and animals has to a greater or less extent modified the native fauna and flora. Dr. John Murray, of the 'Challenger,' has set a good example in this direction by sending a young official from the Natural History Museum to Christmas Island, in the Indian Ocean, one of the few untouched islands

that remain, lying far away from any other land, to the south-east of the Keelings.

What islands are to the ocean, lakes are to the land. It is only recently that these interesting geographical features have received the attention they deserve. Dr. Murray has for some time been engaged in investigating the physical conditions of some of the remarkable lakes in the West of Scotland. Some three years ago my friend and colleague Dr. Mill carried out a very careful survey of the English lakes, under the auspices of the Royal Geographical Society. His soundings, his observations of the lake conditions, of the features on the margins of and around the lakes, when combined with the investigation of the régime of the rivers and the physical geography of the surrounding country, conducted by such accomplished geologists as Mr. Marr, afford the materials for an extremely interesting study in the geographical history of the district. On the Continent, again, men like Professor Penck, of Vienna, have been giving special attention to lakes, that accomplished geographer's monograph on Lake Constance, based on the work of the five States bordering its shores, being a model work of its kind. But the father of Limnology, as this branch of geography is called, is undoubtedly Professor Forel, of Geneva, who for many years has been investigating the conditions of that classical lake, and who is now publishing the results of his research. Dr. Forel's paper on 'Limnology: a Branch of Geography,' and the discussion which follows in the Report of the last International Geographical Congress, affords a very fair idea in short space of the kind of work to be done by this branch of the science. In France, again, M. Delebecque is devoting himself to a similar line of research; in Germany Ule, Halbfass, and others; Richter in Austria, and the Balaton Commission in Hungary. I may also here refer appropriately to Mr. Israel C. Russell's able work, published in Boston in 1895, on 'The Lakes of North America,' in which the author uses these lakes as a text for a discourse on the origin of lake basins and the part played by lakes in the changes studied by dynamic geology. One of the best examples of an exhaustive study of a lake basin will be found in the magnificent monograph on Lake Bonneville, by Mr. G. K. Gilbert, and that on Lake Lahontan by Mr. Israel Cook Russell, published by the United States Geological Survey; the former is indeed a complete history of the great basin, the largest of the interior drainage areas of the North American continent. In the publications of the various Surveys of the United States as well as in the official reports of the Canadian Lake Surveys, a vast amount of material exists for any one interested in the study of lakes; in addition, the elaborate special Reports on the great lakes by the Hydrographic Department. Indeed, North America presents an exceptionally favourable field for limnological investigation; if carried out on a systematic method the results could not but be of great scientific interest.

Rivers are of not less geographical interest than lakes, and these have also recently been the subject of special investigation by physical geographers. I have already referred to Professor Davis's study of a special English river system. The work in the English Lake District by Mr. Marr, spoken of in connection with Dr. Mill's investigations, was mainly on the hydrology of the region. Both in Germany and in Russia special attention is being given to this subject, while in America there is an enormous literature on the Mississippi alone, mainly, no doubt, from the practical standpoint, while the result of much valuable work on the St. Lawrence is buried in Canadian official publications.

But time does not admit of my going farther. I might have pointed out the wide and vastly interesting field presented by what the Germans call Anthropogeography, dealing with the interrelations between humanity and its geographical environment. Geography, Mr. Mackinder has said, is the physical basis of history; it is, indeed, the physical basis of all human activity, and from that standpoint the field for geographical research is unbounded. But I can only hint at this. I have endeavoured to indicate what are some of the leading geographical problems of the future, first in order to show at this somewhat critical epoch how very much yet remains to be done, how many important lines of inquiry are open to the

geographical student, and that the possibilities of our science are, like those of other departments of research, inexhaustible. My aim has also been to indicate by actual examples what, in the conception of British geographers at least, is the field of our subject. We need not trouble greatly about any precise definition so long as there is such a choice of work for the energies of the geographer. I trust I have been, to some extent at least, successful in the double object which I have had in view in this opening address in a country which presents so splendid a field to the practical geographer.

The following Papers and Report were read:—

1. *Kafiristan and the Kafirs. By* Sir GEORGE SCOTT ROBERTSON, *K.C.S.I.*

The paper began with general remarks upon the geographical position of Kafiristan—the origin of the name, which means the Land of the Infidel *par excellence*, according to Muhammedan conceptions. Attention was then drawn to the dissimilarity this country bears to India in climate, vegetation, and in physical characteristics. Kafiristan was described as a highland region with a fairly equable temperature, in spite of great summer heat and heavy snowfall accompanied by severe cold in the winter. It is made up of an intricate network of mountain spurs and ridges, without roads, unless hillside tracks, impassable for horses, and even for dogs in many places, may be so termed. The limited cultivable area is fairly productive. The scenery varies from tiny sloping fields and orchards, from luxurious tangles of wild vines and pomegranates to magnificent pine forests, according to altitude, but invariably includes a large view of profitless hillside and rock. Some of the higher elevations, where villages are to be found, are strangely bleak and inhospitable, and the people have a hard struggle to live. Of the inhabitants many interesting details were given, while their manners and habits were illustrated by a numerous series of lantern slides, made from photographs and drawings. In feature the Kafirs are distinctly Aryan. They seem to be brave after the fashion of the North American Indians, shunning for the most part the open combat, and relying chiefly upon ambushes, night attacks, and surprises. Of course the poorness of their weapons compels these modes of warfare. For the rest, their cupidity, jealousy of one another, and proneness to quarrel make them difficult folk to live amongst. Their political organisation is feeble, each valley being the home of a particular tribe, and sometimes of more than one. Many different languages and dialects are spoken, and internecine strife was rarely intermitted. It is not surprising, therefore, that the Amir of Kabul made an easy conquest of Kafiristan as soon as the disturbances all along the border in 1895 left no chief strong enough to fight for a balance of power against the redoubtable Abdul Rahman. Although no one could say whether the Afghan conquest would be permanent or not, it seemed fairly certain that the Kafir change of religion from paganism to Islam, which has now been enforced, would remain. The alteration could not be for the worse. On the other hand the position and morals of the women, both deplorable, would be improved, the traffic in children as slaves would cease, the endless bloodshed on this frontier might be stopped. Nevertheless the old wild, picturesque life of the Kafirs, terrible and cruel as it was in many respects, was full of the elements of romance. It gave forth, at times, bright instances of bravery, devotion, and personal sacrifice. No one could reflect, without sorrow, on the substitution of self-righteousness, spiritual pride, and austerity, too often hypocritical, for an ancient faith which, degraded as it was, taught its votaries to be masterful and free.

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2. *Report on the Climate of Tropical Africa.*—See Reports, p. 409.

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3. *Novaia Zemlia and its Physical Geography. By* E. DELMAR MORGAN, *F.R.G.S.*

In this paper recent Russian investigations in Novaia Zemlia are summarised. In 1895 an expedition commanded by M. Chernysheff visited this island continent

and passed two months in the southern island, crossing it for the first time from west to east.

The views of von Baer and other earlier explorers that Novaia Zemlia is geologically connected with the Pai-hoi are correct only as regards the southern part and Vaigats; the northern part of the southern island, including both sides of Matotchkin Strait, show a north-westerly strike of the strata, therefore conformable, not with the Pai-hoi, but with the Ural.

The folding process in Novaia Zemlia coincided with the Palæozoic epoch, and from that time denudation forces have been at work. In this way the system of cross valleys has been developed and the well-known Matotchkin shar formed.

The glacial period in Europe was contemporaneous with that of Novaia Zemlia. This was followed by its submergence beneath the ocean, together with vast tracts of Northern Europe, Asia, and America. This submergence reduced the extent of the glaciers in the north or mountainous region, entirely obliterating them in the south, while the formation of deltas dates from the same period.

Novaia Zemlia is now undergoing a new process of glaciation, which will convert it into an icy wilderness.

Various observations concerning other points of interest are contained in the paper.

4. *Sea Temperatures North of Spitsbergen.* *By* B. Leigh Smith.

The author in his schooner yacht 'Samson' left Grimsby on May 16, 1871, with the object of following the Gulf Stream northward. On June 15 he left Tromsö, landed on Bear Island on the 30th, and cruised along the west and north coasts of Spitsbergen, until the middle of September. In 1872 and 1873 these expeditions were repeated, and numerous observations of temperature were made by means of a Miller-Casella thermometer. The result was to prove for the first time the undoubted existence of warm water beneath the cold surface layer. These facts, although communicated to 'Petermann's Mitteilungen' and to Professor Mohn by the author's Norwegian sailing master, have not until this year been published by him.

Table of Temperatures on board the 'Samson,' 1871–72.

Lat. N.	Long. E.	Surface temp.	Depths fms.	Temp. (max.)
° ′	° ′	° F.		° F.
81 20	18 0	33	300	42·5
80 10	6 55	34·5	600	39
80 1	6 36	34	50	37
80 1	6 36	34	200	40
78 34	8 8	37	600	33·5
77 16	4 38	34·5	25	32
77 16	4 38	34·5	250	39·5
76 36	2 14	31	150	39·5
76 21	0 21	36	150	39·5
76 20	0 21	31	200	39·5
76 20	0 54	33	50	40
76 20	0 54	33	200	48·5
75 50	12 55	40·5	100	34·5
75 50	12 55	40·5	250	33·5
75 0	13 15	41·5	100	34
75 0	13 15	41·5	250	42·5
74 39	26 16	32·5	30	34
74 39	26 16	32·5	100	35·5
73 27	20 21	38	100	35
73 27	20 21	38	230	44

FRIDAY, AUGUST 20.

The following Papers and Report were read:—

1. *Scientific Geography for Schools. By* RICHARD E. DODGE, *Professor of Geography, Teachers' College, New York City, U.S.A.*

This paper is a plea for the assistance of geographers in the improvement of geography teaching in America, and particularly the United States. It opens with a general statement of the present condition of geography teaching and of the lines of weakness. The aim of geography teaching being to make the pupils able to gain geographic information for themselves as well as to train their minds and store them with useful facts, the question arises as to how this aim is to be secured. The writer pleads for scientific geography based on a knowledge of the home conditions. He urges that problems in geography be early introduced in the school work, that the pupils may be trained, not only in observation and inference, but in the proving of their inferences. He describes the work in geography done by pupils of eight and nine years of age at the Teachers' College, New York City, the work being carried on by teachers not specially trained in geography.

In no study can scientific training be introduced as early as in geography, and the value is inestimable. The need of the improvement is very apparent, and scientific men should aid in the work.

Assistance can be given by publications of such a character and in such a place that the teachers may come in contact with them and gain from them. There is great need of lectures, and excursions for teachers under the care of scientific geographers. Geographical appliances are in many cases poor and scanty. The aid of the scientific geographer is needed in carrying out and elaborating in other parts of the world the excellent plan of the Geographical Association of Great Britain.

There is also a great need of more publications showing the relation of geography to history and culture, such publications being particularly applied to the needs of teachers.

In these and other ways scientific men can, if they will, assist the teachers to a great extent. The writer urges the co-operation of all in this important work.

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2. *Report on Geographical Education.*—See Reports, p. 370.

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3. *Forestry in India. By* Lieut.-Col. FRED. BAILEY, *late R.E.*

In early times the greater part of India was covered with forest, but the land not cleared for cultivation was, for the most part, denuded by over-cutting and over-grazing with burning. If denudation has not affected the climate generally, it has without doubt resulted in the drying up of springs and streams rising within the areas deprived of the shelter of a crop of trees; and this is a serious matter in connection with the question of irrigation by canals led from rivers which are not snow-fed, as well as in localities where damage has resulted from the formation of ravines and torrents. The permanence of the supply of timber and other forest produce for the use of the native population and for State purposes has also been endangered.

When the Government wished to take action its powers were found to be uncertain, for the destructive usages of the people had come to be regarded as inalienable rights; and it was necessary to pass a special Forest Law, which, among other things, provided for the formation of reserved forests, after a full inquiry had been made into claims, and for the regulation of proved rights within limits which would not endanger the permanent maintenance of the forests. The work of 'settlement' is now approaching completion in several provinces.

In order to secure the forests from over-felling, and to ensure that all work done may tend towards the production of the largest quantity of wood of the kind most desired, working plans are a necessity; and considerable progress has been made in their preparation. During the dry weather the forests become extremely inflammable, and vast areas have been annually burnt over from time immemorial, with the result that the crop is reduced to the poorest possible condition, or entirely destroyed. Measures have been taken to meet this great evil, and large areas are now successfully protected.

The controlling staff of the Forest Department is trained in England, but the candidates follow a course of practical instruction in Continental State forests. The native executive officers are trained at the Imperial Forest School at Dehra Dun.

What has been done could not have been accomplished by private enterprise. The Government has set an example which has been followed by several of the more important Native States. Much more remains to be done, but forest conservancy in India has reached a stage at which its steady progress cannot be arrested.

4. *A Scheme of Geographical Classification.* *By* Hugh Robert Mill, *D.Sc., F.R.S.E.*

A classification of any branch of knowledge is necessary for the purpose of recording the several contributions of specialists, and the following scheme of geographical classification has been worked out practically during the elaboration of a subject catalogue of geographical literature. The essential primary division is into general and special geography. The former, which might equally well be termed pure or abstract geography, includes all general considerations which do not depend upon particular places; the latter reduces itself to an index of positions. It would be served most completely by employing latitudes and longitudes; but practically political subdivisions must be used.

The first principle in the classification of each great division is to group together facts of approximately the same order; thus, *e.g.*, we might take the continent as the first order of classification in the second division, the country as the second, and the province and county as the third and fourth. It would be fatal to the logical completeness of any scheme to mix up the three orders in one category. The number of orders to be adopted would depend to some extent on the detail required, but practically four would suffice, and in many cases three. A convenient notation would facilitate classification, and one is suggested in the paper whereby the various orders are distinguished by letters of different type and by numerals.

Outline of Classification.

Geography, General. [To the second order.]

Mathematical Geography in general:—
- Geodesy.
- Surveying.
- Cartography.
- Globes and models.
- Geographical instruments.

Physical Geography in general:—
- Geomorphology.
- Mountains in general.
- Earthquakes.
- Glaciers.
- Lakes.
- Rivers.
- Climatology.
- Oceanography.

Bio-Geography in general:—
- Distribution of plants.
- Distribution of animals.

Anthropo-Geography in general:—
- Ethnography.
- Historical geography.
- Political geography.
- Commercial geography.
- Geographical education.
- Place names.
- Geographers' biographies.

GEOGRAPHY, SPECIAL. [Divisions of the first order only.]

The Earth as a whole.

THE LAND as a whole.
EUROPE.
ASIA.
AUSTRALASIA.
PACIFIC ISLANDS.
AMERICA as a whole.
NORTH AMERICA.
CENTRAL AMERICA AND WEST INDIES.
SOUTH AMERICA.
AFRICA.
POLAR REGIONS.

THE OCEAN as a whole.
ATLANTIC OCEAN (seas and islands as subordinate divisions).
INDIAN OCEAN (seas and islands as subordinate divisions).
PACIFIC OCEAN (seas only).
SOUTHERN OCEAN.

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5. *On the Distribution of Detritus by the Sea.* *By* VAUGHAN CORNISH, *M.Sc., F.R.G.S., F.C.S.*

The object of this investigation is to explain the processes which distribute the detritus that enters the sea at its margin. The processes can be deduced from the observed mode of occurrence of terrigenous materials on the foreshore and on the sea bottom, from the mode of occurrence of the rocks, from the motions of sea water, from the circumstances of attrition, from the behaviour of dust, and from the motions of individual pebbles and grains of sand.

The author deals in considerable detail with the motions of water due to tides and waves, and the transporting effects of these motions.

It is shown that the transport of fine mud downhill from the coast seawards is not due to the action of gravity.

Shoals and beaches (persisting structures of changing material) are dealt with in a manner similar to that employed by the author in the study of sand dunes ('Geographical Journal,' March 1897).

It is shown that the usual reasoning from the behaviour of individual pebbles and sand grains to the behaviour of beaches is vitiated by the neglect to take account of the fact that the variation in the proportion of the ingredients greatly exceeds the variation in the mobility of the individuals.

The paper, which will appear *in extenso* in the 'Geographical Journal,' comprises the following heads: viz., The Motions of the Sea, Mud Flats of the Deep Sea, The Sifting of Sand from Shingle, The Formation of a Shingle Beach, The Origin of the Ridge and Furrow Structure of a Shingle Ness, The Grading of Beach Material (under which heading the case of the Chesil Beach is discussed), Sandy Beaches, The Origin of the 'Low' and 'Ball' of a Sandy Shore, The Accumulation of Sandy Forelands and Sandbanks, and The Contours of Coasts.

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6. *On certain Submarine Geological Changes.* *By* JOHN MILNE, *F.R.S., F.G.S.*

This communication was largely an epitome of a lengthy paper on 'Suboceanic Changes' published in the July and August numbers of the 'Geographical Journal.' To this, however, a few new but important observations were added.

The author pointed out that the general result of denudation on the land was to bring materials to a lower level, and by gradually wearing away excrescences like mountain heights to render such forms more stable. Beneath the sea these materials are accumulated in slopes, which, being formed largely under the influence of gravity, are unstable. As the deposits grow, from time to time facial slidings take place from weight alone, and from the escape of fresh water from subterranean springs. The most important cause of submarine landslides are the

shakings accompanying submarine earthquakes, these disturbances resulting in effects at least equal to, but probably greater than, those we see produced upon the land. Observations conducted over many years have shown that earthquakes, which are announcements that adjustments in strain or isostasy of rock masses are in progress, are much more frequent along the submerged slopes of the continental plateau than they are on land, which leads to the conclusion that the districts of greatest secular movements on the surface of our planet are to be found beneath the ocean. The best evidence for these facts is furnished by submarine cables.

Besides interruptions due to waves, the borings of teredo, and other operations in shallow water, we have a class of interruptions at comparatively great depths, in some instances exceeding 2,000 fathoms. In almost all these instances, which do not occur in the flat plains of ocean beds, but along the edge of submarine banks and the edges of the submerged continental frontier, the cables are apparently buried by the sliding downwards of large bodies of materials from higher levels. The result of this is that it has often happened that two or three cables, 10 or 15 miles apart, have been destroyed simultaneously. Many examples were given where an earthquake, more or less severe, has been felt on land, and at the same moment a cable has been broken. In some instances when this has occurred, an impulse has been given which has thrown an ocean like the Pacific into a state of agitation for a period of one or two days.

When these submarine disturbances have been great the resultant earth movement has been such that, with suitable instruments, it might be recorded at any point upon the surface of the globe.

The most remarkable observations connected with submarine earthquakes are, however, those which have resulted in changes of depth up to at least 200 fathoms over considerable areas. To study these submarine dislocations, and to determine whether cables have been interrupted by artificial operations such as accompany war, or by natural means, horizontal pendulums which will record the unfelt movements of the earth's crust should be established round the shores of all our continents and on oceanic islands. The importance of these observations to our colonies must be apparent.

Another set of phenomena which promise to throw light upon the fluctuations in the enormous strains within the rocky envelope of our planet, which sometimes culminate in fractures, 100 or more miles in length, are the records of magnetometers. The effect of torsional and other strains on the magnetic conditions of iron and nickel is well known, and it may reasonably be supposed that kindred effects may be induced by strain in rock-masses. At all events, at three magnetic stations on the coast of Japan, commencing in one case a week, and in another about two weeks, before the great earthquakes of 1896 in that country, the instruments showed marked but abnormal movements, these being greatest at the station nearest to the seismic foci. They reached a maximum some hours before the shocks took place, after which unusual displacements ceased.

Should future observations confirm that which is here noted, we shall then have at our disposal another method of gaining information of changes in operations, the scene of which is hidden from our view not only by the oceans but by the solid rock.

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7. *The Congo and the Cape of Good Hope*, 1482 *to* 1488. *By* E. G. Ravenstein.

The discovery of the Congo and of the Cape of Good Hope constitutes two of the most interesting episodes in the history of geographical exploration. Apart from the legends on Behaim's globe, which must be accepted with caution, not a single original report by one of those who took part in these voyages has reached us, and hence the information given even in the best accredited histories of geographical exploration is erroneous in several important particulars. Recently, however, the inscriptions upon some of the columns set up by the early Portuguese navigators have been deciphered; several ancient manuscript maps have become

available, and even one or two contemporary documents bearing upon the subject have seen the light. This enables us to give a more trustworthy account of these early voyages.

When King Alfonso died in 1481 the whole of the western coast of Africa, as far as Cape Catherine, had been discovered. King John, his successor, entered heart and soul into the business of exploration so successfully carried on by his ancestors. In 1482 (and not 1484) he despatched Diogo Cao on his first voyage, which led to the discovery of the Congo and of the coast to the south of that river as far as lat. 13° 27′ S. After his return, on April 14, 1484, the explorer was knighted, and figures of the two columns which he had erected were introduced into the coat of arms which was granted him. He set out again almost immediately, and succeeded in revealing the coast as far as Cape Cross in lat. 21° 53′ S. If a legend on Germano's old chart can be trusted, he never returned from this expedition, but died near the last column erected by him. Martin Behaim claims to have commanded one of the ships of this expedition; and although it is possible that he was a member of it, he certainly did not play the important part as captain or 'cosmographer' which he claimed. His reputation is based upon a globe the manufacture of which he superintended at the request of the town council of his native town, Nurnberg (1492), and a passage in Barros' 'Asia,' which mentions him as a member of a board of mathematicians, instituted by King John to devise a method of determining latitudes by means of meridian altitudes of the sun. This, however, is all a myth. Long before the time of Behaim, and even before Regiomontanus, his alleged teacher, such tables had been prepared by Zacuto, a learned Spanish Jew, and these tables, as also the astrolabe, were in use among Portuguese mariners long before Behaim first came to Lisbon, in 1484, and there is no reason to assume that Behaim ever took an interest in scientific work. His globe shows that he was thoroughly incompetent, for in laying down the part of the coast which he claims to have personally visited he errs to the extent of 24 degrees in latitude.

In 1486 an expedition from Benin brought news that there resided, at a considerable distance in the interior, a powerful Christian king, who was at once identified with 'Prester John' of Abyssinia. King John forthwith despatched two expeditions, both of which started in 1487, the one, including Paiva and Covilhao, by land, the other, under Bartholomew Dias, by sea. Covilhao reached India, journeyed along the east coast of Africa as far south as Sofala, and ultimately entered Prester John's country. Dias doubled the Cape of Good Hope, probably, at the beginning of 1488, and followed the coast as far as the Great Fish River, when his crews insisted upon being taken home. Thus the possibility of reaching India by sailing all round Africa had been demonstrated, and the realisation of the far-reaching plans of Henry the Navigator only became a question of time.

SATURDAY, AUGUST 21.

The Section did not meet.

MONDAY, AUGUST 23.

The following Papers were read:—

1. *Institutions engaged in Geographic Work in the United States. By* MARCUS BAKER, *Vice-President of the National Geographic Society.*

The paper, written at the suggestion of the Hon. Gardiner G. Hubbard, is a summary account of the principal Federal and State organisations which have conducted important geographical explorations and surveys in the United States

during the century: it is designed to give such an account of these institutions, of their history and of their methods and results, as will bring out the relations among the institutions and introduce a somewhat more detailed account of the work of particular surveys and bureaus presented by other American representatives.

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2. *A Brief Account of the Geographic Work of the United States Coast and Geodetic Survey. By* T. C. MENDENHALL, *formerly Superintendent of the Survey.*

This paper begins with a summary sketch of the history of the United States Coast and Geodetic Survey since its creation in 1807, and proceeds to describe the development and improvement of methods, as well as the extension of the work from the bays and harbours of the middle Atlantic slope to all portions of the American coast. The methods, purposes, and results of the transcontinental triangulation are set forth, together with leading features of the work in the measurement of gravity for the purpose of determining the figure of the earth and controlling the detailed surveys. The precise determination of latitudes and longitudes is also described, and the methods and extent of mapping are indicated. Reference is made also to the preparation of the coast pilots and to the determination of terrestrial magnetism, &c.

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3. *The Hydrography of the United States. By* F. H. NEWELL, *Chief of the Division of Hydrography* of *the United States Geographical Survey.*

This is an account of the development of hydrographic surveys in the United States up to the present date. All of those surveys are relatively recent, and it is shown that the period of exploratory work has passed—already the locations of streams and lakes are known. The second stage of progress in which the volume and fluctuations of the water are ascertained has been entered upon; the study of the applications of these determinations to welfare is just beginning. The field of investigation is first outlined, and the purposes of the investigation are set forth; then the investigations are described in some detail for the purpose of indicating methods and suggesting applications; and the paper closes with a summary statement of results.

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4. *The Coastal Plain of Maine. By* Professor WILLIAM MORRIS DAVIS.

Southern Maine is bordered by a narrow and irregular coastal plain, dissected by numerous small valleys. It is ordinarily the case that coastal plains are limited by sub-parallel lines marking the former and present shore line of the region, as may be seen in the typical example that skirts the eastern margin of the Deccan in India. But the coastal plain of Maine has a most irregular inner and outer boundary, and its surface is interrupted here and there by ridges and hills of rugged rocky surface, similar to that of the oldland further inland. The inner boundary or former shore line is irregular, because it marks the edge of a partly submerged hilly region at the time the clayey strata of the plain were accumulating. The outer boundary is irregular, because the period of submergence and deposit did not endure long enough to produce a smooth sea-bottom; hence, when the plain was revealed by elevation, the new shore line was little less ragged than the old shore line, and time enough has not yet passed for its simplification, even by the strong Atlantic waves. The streams and rivers, extended from the oldland across the plain, have incised valleys along their consequent courses. Thus the surface of the plain is to-day of moderate inequality of form. At many points the streams have cut down their channels upon buried ledges, and thus falls are developed. In coastal plains of simpler form such falls occur only near the inner border of the plain; here they may occur close to the outer border, and this is no

small advantage, as it gives the largest possible volume to the fall and places it near sea transportation.

Although of small area and modest relief, the coastal plain of Maine between the oldland behind it and the sea in front exercises a manifest control on the distribution and occupation of the people. The irregular shore line affords many harbours; here fishermen and boatbuilders are found. The numerous waterfalls define the sites of manufacturing villages and cities. The smoother parts of the plain are occupied by farmers, who utilise the adjacent ridges and hills of the oldland for pasture and woodland. The oldland itself, unless well sheeted with glacial drift, is rugged and inhospitable, and the sad little farms in occasional clearings there are in marked contrast to the thrifty and well-to-do houses and barns on the plain itself.

5. *The Unification of Time at Sea.* *By* C. E. Lumsden.

6. *The Barren Lands of Canada.* *By* J. B. Tyrrell, *M.A., B.Sc.*

The 'Barren Lands,' or more properly the Northern Plains and Prairies of Canada, cover an area of about 400,000 square miles between the Mackenzie River and Hudson Bay, extending from the coast line of the Arctic Ocean down to the general northern limit of the forest. On the west coast of Hudson Bay they reach southward to north latitude 59°, and thence their southern boundary extends in a north-westerly direction, roughly at right angles to the magnetic meridian, to within a short distance of the mouth of the Mackenzie River, crossing the Kazan at Ennadai Lake, the Telzoa River at Boyd Lake, and keeping some distance back from the shore of Great Slave Lake.

In general character the country is a vast undulating, stony plain, thinly covered with short grass, while rounded rocky hills rise here and there through the stony clay. It can be divided into two fairly distinct portions, viz., the 'Coastal Plain,' which rose from beneath the ocean in post-Glacial times, and the 'Interior Upland,' with a somewhat more pronounced topography, just as it was left at the close of the Glacial epoch.

The whole country slopes gently towards the north-east, and the three main streams which drain it have a more or less parallel course in that direction. These streams are the Back or Great Fish River, with a total length of 650 miles; the Telzoa or Doobaunt River, with a length of 750 miles; and the Kazan River, with a length of about 490 miles.

The author showed illustrations, drawn from photographs, exemplifying the general character of the country, its herds of reindeer, and its native inhabitants.

7. *Geographic Work of the United States Geographical Survey.* *By* Charles V. Walcott, *Director of the Survey.*

The paper begins with the summary sketch of geographic surveys in the United States prior to the organisation of the United States Geographical Survey in 1879, and then sets forth the methods and progress of the geographic surveys conducted by this bureau. The surveys are designed for mapping on scales of 1 : 62,500 and 1 : 125,000; and the work is drawn and engraved on copper in the office of the survey; the mapping is in sheets, each covering a quarter of a square degree for the larger scale and one-sixteenth of a square degree for the smaller scale, and each is engraved on three copper plates for printing in three colours—black for the projection and culture, &c., blue for the hydrography, and brown for the hypsography or vertical relief (which is expressed in contours). The purpose of these maps is to form a basis for the geographical surveys and the general geological maps of the United States, which it is the primary function of the survey to execute. The geographic surveys have already extended over about 760,000

square miles, and are represented on nearly a thousand map sheets. The author proceeds finally to point out some of the various uses of the survey and resulting facts in addition to the purely geologic applications.

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8. *The Topographical Work of the Geological Survey of Canada.* *By* J. WHITE.

This paper treats of the topographical work of the Geographical Survey from its inception in 1841 to the present time.

In the absence of anything like a general geodetic survey of the Dominion the Geological Survey, as the only organisation charged with the mapping of the country as a whole, has been forced to undertake extensive surveys and explorations.

The operations in the field may be divided under two heads:—

1. The reconnoissance and exploratory surveys of the unexplored and the less accessible areas of Northern and Western Canada.
2. The detailed surveys, for mapping on regular scales, of the more accessible and the settled portions.

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9. *The United States Daily Weather Survey.* *By* Professor WILLIS L. MOORE, *LL.D., Director of the United States Weather Bureau.*

It is the purpose of this paper to present a summary sketch of the work of the Weather Bureau in ascertaining the various features controlling climate in the United States and in adjacent territory. To this end the growth of the bureau is sketched and the methods pursued in various stations and offices, extending from the Pacific to the Atlantic, are described. Special note is made of recent extensions in the service into Mexico on the south-west and Canada on the north, and plans for extending the work into the West Indies are developed. Special attention is given also to the recent improvement in forecasting through the use of kites, by which the condition of the air is determined at altitudes of one to two miles above the land surface.

TUESDAY, AUGUST 24.

The following Papers were read:—

1. *The Economic Geography of Rhodesia.* *By* F. C. SELOUS.

The author traces the history of the British occupation of South Africa, and goes on to discuss the economic geography of the country, mainly with regard to agriculture.

The form of the land, an elevated plateau, insures a generally healthful climate, and avoids the most serious drawback to European colonisation in tropical Africa. Fever is still common in many parts, but may be confidently expected to disappear in the more elevated regions when the land is cultivated and the swamps are drained. The superior healthiness of Western Matabeleland is attributed to the fact that for sixty years the land has been cultivated by a relatively dense population.

With regard to agriculture and cattle-rearing, the present visitation of rinderpest is an epidemic, and not the usual condition of the country. Locusts, which have recently wrought much damage to crops, come periodically, but in ordinary times Rhodesia is healthy for cattle and fertile for grain. Irrigation will achieve much in many parts of the country. There may never be a great export of agricultural produce, but Rhodesia bids fair to be self-supporting and to supply the whole population drawn into the country by its mineral wealth.

Details are given in the paper drawn from the author's residence in South Africa for twenty-five years.

2. *A Journey in Tripoli.* *By* J. L. MYRES, *M.A.*

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3. *On the Direction of Lines of Structure in Eurasia.* *By* Prince KROPOTKIN.

The aim of this paper is to put in evidence the importance of certain directions which prevail in the main lines of orientation of plateaus and chains of mountains in Asia and Europe. The very important part played by erosion and denudation in the shaping of the orographical features of the continents is well known; but even after that agency has been fully taken into account, we find in Eurasia two main directions which are followed by the chains of mountains and the plateaus; namely, from S.W. to N.E., and from N.W. to S.E., or rather from N.W. by W. to S.E. by E.

In Asia, the prevalence of these two directions is quite evident. Of the two great plateaus which make the backbone of Asia—the Asia Minor plateau and the great plateau of East Asia—one runs N.W. to S.E., and the other runs S.W. to N.E. The border ridges of these plateaus, as well as the ridges which are situated on the plateaus, and the Alpine tracts which fringe them all follow the one or the other direction. And the better the orography of Central Asia is known the more distinctly these two directions appear on our maps.

The broad features of the orography of East Asia which were mapped out by the author in 1876 were extended by Petermann to the south-western parts of Central Asia, and were embodied into his map of Asia for Stieler's Atlas. They seem now to be pretty generally accepted. The Stanovoi Khrebet, which ran W. to E. on our older maps, has disappeared; the high plateau with its lower terrace and the Great Khingan bordering that lower terrace, as well as the series of parallel ridges running N.E., parallel to it, which he ventured to indicate then, are by this time figured on most of our maps. It may be said that the investigations which were made within the last twenty-five years further and further confirmed this conception of East Asia's orography. The Nan Shan system, the Altyn-tagh, and the several chains of the Kuen-lun; the mountain ridges of the Darvaz; the high chains of the Khan-Tengri system; the Great or Ek-tag Altai; and the mountain ridges on the middle Hoang-ho, which all were traced twenty years ago in all directions, take now on modern maps the orientations S.W. or N.E., or N.W. to S.E. And we see more and more distinctly appearing on the maps of Asia that immense plateau—extremely similar to the great plateau of Western North America, though directed N.W. instead of N.E.—which divides Asia into two parts, entirely differing from each other in their climate, vegetation, and all general geographical characters; so much so that the vegetation on the S.E. slope of the great plateau (Amur region) is much more like to the vegetation of British Columbia than to the vegetation of West Siberia.

Professor Mushketoff's researches in the Tian Shan have revealed another fact of very great importance; namely, that the upheavals running towards the N.E. are the oldest ones (Archæan or Palæozoic), while those chains of mountains which run S.E. to N.W. are more recent—that is, belong to the Mesozoic times.

In Europe the same two directions have the same prevalence. The Urals appear now to consist of upheavals, or rather of mountains and plateau slopes running alternately N.E. and N.W. The leading feature of Scandinavia's orography are: lines of high plateaus running N.E. into the peninsula of Kola, and a lower terrace running also N.E., from Scania to Finland. In Russia the dominant feature (altered here and there by erosion) is the central plateau, which runs from the Carpathians to the Middle Urals, all physical and even economical features of the country (fertility of the soil, crops, &c.) being subordinated to this leading feature. In Caucasia and Asia Minor the plateau which stretches from West Armenia to Daghestan (S.W. to N.E.) and the main chain running N.W. to S.E. are the dominant features.

In Bosnia, Montenegro, Albania, and Macedonia the N.W. direction prevails, while the north-eastern prevails in the Alps. In the Pyrenees we find (as in the

Urals) a complex of two chains running N.W. in the centre (Schrader's Map), and two chains running N.E. on both ends of the main *massif*; while the Sierras de Estrella, de Gata, de Gredos, and Guadarrama, and the chains of Sierra Morena of Murcia and Granada assume the N.E. direction. The central plateau of France and the mountains of Scotland are again instances in point.

Of course these two directions are not exclusive. The eastern Tian Shan, some mountains of Minusinsk, and, may be, the Balkans are instances of the W. to E. direction, and faint traces of meridional upheavals (which may continue even now to be going on) may be indicated. Chains *en échelon* (Spain, North Asia) must also be mentioned; as also curved border ridges grown on the edges of plateaus, especially along the N.W. border of the high plateaus of Asia, where the deepest depressions lie at its borders (southern shore of Caspian, Lake Baikal). Various causes may contribute to produce this growth of mountains along the edges of plateaus, especially if these chains have originated at a period when the plateaus were continents surrounded by the ocean.

The fact that the two great plateaus of Asia and North America—the two oldest backbones of the two continents—converge towards Behring Strait, in the same way as at the present time the continents have their narrow extremities pointing towards the South Pole, deserves a special attention. This fact may be one more confirmation of the hypotheses which look for general telluric, or even perhaps cosmical causes in order to explain the origin of mountains altogether.

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4. *Potamology as a Branch of Physical Geography.* *By* Professor ALBRECHT PENCK, *Vienna.*

The paper shows the necessity of a profound study of rivers as a department of physical geography, equivalent to oceanography and limnology. This branch may be called *potamology*. It can be treated under five different heads—

1. The physics of running water.
2. The bulk of water and its fluctuations.
3. The action of water on its bed.
4. The distribution of rivers on the earth.
5. The rivers as a scene of organic life.

The author points out that the physics of running water are not known to such a degree that a formula for the mean velocity could be established, the existing ones being in general incorrect. He farther gives an account of some new results obtained by him concerning the bulk of water of Central European rivers and its relation to precipitation; he expresses the wish that measurements of the quantity of water of the larger rivers should be undertaken, and that the results of gauge-observations should be published in a regular way, as are the results of meteorological observations. He proves the necessity of studying the movement of river gravels, and of publishing maps of river-bottoms. He shows that there is still a want of exact knowledge of the magnitude of river-basins and river-lengths of European and North American rivers, and refers to some difficulties in determining those quantities. As to rivers which by climatic causes are not constantly running, he agrees that extreme values of their catchment basins and lengths should be determined. While acknowledging what had been already done for the study of rivers for practical purposes (irrigation, floods, navigation), he holds that much remains to be done in order to establish a scientific potamology.

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5. *Geographical Development of the Lower Mississippi.* *By* E. L. CORTHILL.

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6. *South-eastern Alaska Geography and the Camera.* *By* OTTO J. KLOTZ.

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7. *The First Ascent of Mount Lefroy and Mount Aberdeen.* *By* Professor H. B. DIXON, *F.R.S.*

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8. *Mexico Felix and Mexico Deserta.* *By* O. H. HOWARTH.

The physical structure of the region comprised in the Mexican Republic, viz., that of a high plateau of some 550,000 square miles in area, fringed by a narrow belt of low-lying lands on either coast, has led to its being usually described under three climatic divisions—the Tierra Caliente, or Hot Lands, the Tierra Templada, or Temperate Lands, and the Tierra Fria, or Cold Lands. For practical purposes such a description can hardly be said to afford any strict geographical definition, inasmuch as the climatic conditions of any particular locality are not dependent only on temperature, but also on altitude, rainfall, evaporation, forest growth, proximity of ocean waters, and other modifying causes, all of which operate in varying degrees at different latitudes. Omitting the coast levels, which are essentially tropical in character, though not wholly within the tropical limits, and the higher mountain ranges of the interior, it is to be observed that the general characteristics of that portion of Central America are still subject to much misapprehension in the minds of those unacquainted with Mexico. Regarding the conditions of human life and prosperity, it occurs to me that the general distinction into 'Mexico Felix' and 'Mexico Deserta' is somewhat more to the purpose; and it will be seen that those conditions have little to do with mere temperature by itself—still less with actual latitude.

From a breadth of some 1,200 miles at the United States frontier, on about the 30th parallel, the continent narrows gradually throughout its south-easterly trend to one of only 120 miles at the Isthmus of Tehuantepec, widening again at the borders of Guatemala, some 14 degrees further south, before it contracts finally to a 45-mile strip at Panama. From the general altitude of 3,000 to 4,000 feet, extending through the south of Arizona, New Mexico, and Texas (U.S.A.), there is a further gradual rise beyond the course of the Rio Grande, and a general level of 5,000 feet and upwards is maintained for 1,200 miles, until, south of the city of Mexico, it declines again by a series of terraces to under 2,000 feet, mounting up once more in the States of Oaxaca, Guerrero, and Chiapas. Yet the mean temperatures and evaporation are considerably higher, and the rainfall lower, in the northern portion of this tract than in the south, which is commonly supposed to belong to the torrid regions of the earth. While the mean temperature during last year in the city of Mexico was slightly under 60° (Fahr.) that of Monterey, in the State of Nuevo Leon, was over 74°; whereas at the city of Oaxaca, 300 miles further south than Mexico City, and at 2,000 feet less elevation, it was no more than 67°. The northern States of Chihuahua, Coahuila, and Nuevo Leon preserve largely the characteristics of Nevada and Arizona, comprising vast arid plains of sage-brush, mosquite, and cactus, intersected by treeless mountain ranges, and forming a zone between the regions of winter and summer rains upon which the latter intrude but sparsely and only in occasional seasons. Hence it is that in the southern States of North America the higher rainfall, together with the altitude and approximation of the oceans, has developed a climate both healthier and more equable, and a vegetation which in the north is only found in patches or amongst the heights of the coast ranges.

Perhaps the evidences of this peculiarity which possess the most direct interest for us are those bearing upon the population of these southern regions in remote ages, the study of which is rapidly leading us to assign to them an antiquity at least as great as any of which the world holds any record.

WEDNESDAY, AUGUST 25.

The following Papers were read :—

1. *The Material Conditions and Growth of the United States.* *By* HENRY GANNETT.

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2. *Geographical Pictures.* *By* HUGH ROBERT MILL, *D.Sc., F.R.S.E.* (*With Lantern Illustrations.*)

In view of the prominent place now taken by photography in the work of all travellers it is necessary to urge the importance of taking pictures which are geographically as well as photographically 'good.' Such pictures must be truthful and representative, the utmost care being taken to avoid distortion, to supply some indication of scale, and to bring out the characteristic features. General views comprehending a considerable area are desirable for showing types of land-forms or sites of towns. Pictures on a larger scale are desirable for showing the detail of special features, such as varieties of architecture, means of transport, or agricultural processes related to certain geographical conditions. As far as possible every geographical picture should show something distinctly illustrative of a natural feature or a local condition peculiar to the place where it was made, or at least characteristic of it. The handsomest house in a village, the rarest foreign tree in a park, or the prettiest view in a district, represents the sort of subject most often photographed, and they are precisely those of least geographical value. The paper was illustrated by numerous lantern views of typical scenery, people, and processes of geographical significance.

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3. *Geographical Wall-pictures.* *By* Professor ALBRECHT PENCK.

Geographical education needs means of representation. The student should not have only the knowledge of facts, he must be enabled to represent to himself the features of the earth's surface. There cannot be any doubt that lantern slides afford a very good means for helping to get such clear representations as are needed, but, on the other hand, other means of geographical representation may not be neglected. The projections of lantern slides are of a mere temporary character, excellently fitted to illustrate the spoken word, but education needs also means for impressing deeply the most important features of the earth's surface into the minds of the students.

At Vienna we use for this purpose with the greatest advantage the geographical pictures issued by the establishment of Edward Hobsel. These are printed in different oil-colours, the size of each being 32 : 24 inches. The whole collection embraces now thirty-seven pictures (the price of each being 4*s.* = $1.00); the greater part (twenty-three) indeed represent European features, but more than one-third represent sceneries of other continents, and six give American views. The high educational value of the collection concerns the morphology of the earth. Five pictures represent different types of vegetation forms, the tropical virgin forest, as well as the Hungarian steppes; nine the forms of the highest mountain ranges in Europe, North America, and Asia, with their glaciers; four show the different actions of water; seven pictures illustrate the formation of valleys and the whole cycle of land-destruction; four show volcanoes in different parts of the world; eight represent types of coastal formation.

The Hobsel collection of the geographical character pictures is now completed by a set of geographical city pictures of larger size. The pictures of London, Paris, and Vienna have already appeared. There is also a very good collection of historical wall-pictures edited by the establishment of Hobsel. The collection embraces sixty-two sheets, executed after drawings of Professor Langl.

4. *Geography in the University. By* Professor WILLIAM MORRIS DAVIS.

Geography is inherently of sufficient interest, importance, and disciplinary value to deserve a place in the university on an equal footing with history. Without such recognition the scientific development of the subject must languish, as would that of any other subject not represented in higher education. A full development of geography as a university study requires due attention to its two parts—the physical environment of man on the one side and his way of responding to environment on the other side. After due preparation on these fundamental subjects, the geography of continental or other areas may be taken up.

Two advantageous results may be expected from the full recognition of geography as a university subject. The first is an advance in the status of geography in the lower schools, where it is now too often in an unfortunately degraded condition. The second is a more thorough and scientific record of travellers' observations, which are now too often merely personal narratives of adventure, with little of serious geographical matter.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—E. C. K. GONNER, M.A., Professor of Economic Science in University College, Liverpool.

THURSDAY, AUGUST 19.

In the absence of the President the following Address was read by the Hon. Sir C. W. Fremantle:—

IN the selection of the subject on which I propose to offer, according to custom, a few remarks to-day, I have been influenced by the wish to choose one which is not only of present importance, but such that it may provide occasion for the discussion of the advance which economic study has made, and of the methods whereby that advance has been achieved. The position of the Labour Question in modern thought and its economic treatment is a matter well worth attention from these various points of view. In addition, its consideration cannot fail to throw light on the connection which exists between the economic growth of a country and the main developments of Economics as a study. Whatever their view of the subject itself, few will deny the curiously emphatic position occupied by Labour and the various questions relating to it and its conditions at the present day. Illustrations present themselves on many sides. Evidence may be adduced from almost all quarters of literature, even from those seemingly unlikely. To the novel writer and the novel reader working-class life has formed a continent almost as newly discovered as that sighted by Columbus and others, or rather by others and Columbus, in the fifteenth century; and even when the novelist is chastened into unnecessary discretion and distant allusiveness in his description of detail and habits by the fear, perhaps the unnecessary fear, that his audience is less ignorant than himself, Labour Problems and Labour Difficulties brood like a nightmare in his mind and leave their mark on his pages. It is the same in other literature, where they reign in almost undivided monopoly. The 'working man' button-holes the reader in the library and at the news-stall, and stays beside him in the very discomforting guise of a problem when he sits by the fireside in the evening. And as in literature so in life, as in life so in public discussion. On all sides there is the same feature. In all directions there has grown up the same tacit habit of regarding each question as hardly worth discussion till it has passed the preliminary test not only of its effect on the position of the working class, but of the view they are likely to take of it; rightly, no doubt, inasmuch as it implies the consideration of their interests, often neglected in the past; wrongly when construed into the conclusion that all measures or changes which they resent are necessarily evil. A similar tendency is shown in recent economic literature, and particularly in that of the past quarter of a century, which treats of the conditions and remuneration of manual labour with force just as undeniable as the length of the chapters and the number of the books devoted to the subject. What may be termed the bias of economic studies is very evident. Just as at one time

the balance of trade and commercial relations with foreign countries, and at another currency schemes and currency iniquities, pervaded the atmosphere, so now Labour and the Labour Question, and writer after writer struggles beneath its fascination, helpless in his efforts to avoid its introduction in every part of his work, suitable or unsuitable. Like the reference to the head of a departed English monarch, it forces an entrance page by page and chapter by chapter. What a revenge time has brought with it for former neglect! How great the present prominence is and how recent is shown by a comparison between the subjects discussed to-day and those discussed at the beginning of the present or during the past century, between the general trend of an economic treatise now and that of those of the past. Then Labour itself was the subject of bare reference as an agent of production, and as one, but by no means the chief, factor requiring payment, and in only a few cases were there traces that its condition and its environment were even regarded as matters for economists to discuss, while now there is the risk of other elements escaping attention. It is not the way in which the subject is dealt with that is insisted on here, but the bare prominence of the subject, though the former in its turn has changed greatly, the somewhat rigid impassiveness of the earlier date yielding to expressions of a vivid and personal sympathy.

On turning to what is the *first* portion of our task—the consideration of the causes which have made thus conspicuous one agent in production and one economic element—the identification or rather the confusion of labour with labour of one grade calls for remark. Labour is the term used to denote either the work of one class, the class, that is, which monopolises the title of the working-class, or all human work necessary to production. In some instances the term is stretched so far as to include all effort, direct or indirect, involved in production. But though instances of these different meanings are found in abundance, and though the second of them is the most strictly consistent, as it expresses the distinction between personal effort and that which is not personal, *Labour* when used emphatically and spelt with a capital initial is almost invariably, so far as popular usage is concerned, taken as implying some particular reference to the grade of manual labour. Other labour, skilled labour or labour of management, if included at all, is treated as comparatively insignificant. To all intents and purposes by labour, especially when conditions and remuneration are referred to, is meant manual labour. This restriction in definition is significant and unfortunate. Associations centring round labour in the wider sense come almost imperceptibly to be conceived of as relating to labour in the more narrow meaning of the word. Coincident with its growth in popular favour, the tendency to restrict the term has increased. It is true, of course, that in economic writings labour, when defined, is applied to personal action of all grades and of all degrees of skill, but even there laxity finds entrance in the frequent unguarded use of slipshod popular expressions, as the difficulties of labour, the labouring classes, conflicts of labour and capital, and the like, when by these are meant the difficulties and interests of one class of labour only. Such, then, is the aspect which confronts the student of social phenomena in the present day. Considerations respecting Labour have acquired, and that comparatively recently, an unusually large share of attention at the very time when the term, in popular usage at any rate, has been shorn of some part of its meaning and severely restricted in definition.

The causes of the new prominence of this class of labour form a subject of much importance, for on our knowledge of them largely rest the conclusions as to the true significance of the problem and the meaning of such results as we discern. Such knowledge also provides the means of discriminating between changes due to direct economic movements and those arising out of nothing more than an altered attitude on the part of society brought about by general causes.

To some, no doubt, the explanation of this particular change, and of the prominence of this question, lies in the greater humanity which characterises the economic thought of the present as contrasted with the past; to others, in the wide extension of the franchise, and the admission to political power of the classes whose interests lie in the above direction; while others again believe that they

find it in the subtle changes in the general conceptions of a restless and singularly receptive society. But these various impulses, important though no doubt their influence has been, are very general in character, and seem hardly definite enough to account for a change in thought so distinctive and so unrelieved in its nature, while all of them are open to the pertinent criticism that they themselves may be due in part, and in large part, to modifications in economic circumstances. Were they, or any of them, the sole or even the principal cause, it is hardly necessary to add that the alteration which has taken place has been in the way of looking at things, and not in things which are looked at. Others, again, have found their answer in the greater degree of certainty and assurance with regard to economic elements which in earlier times constituted difficulties in the way of progress and menaced considerable dangers, and it is true that much that may be urged in this direction is well founded. Capital which, at the beginning of the present century, was in imminent demand and vastly insufficient for the development of industry, has grown, not by any slow if certain increase, but by leaps and bounds just as certain, and its accumulation under the most varying vicissitudes has removed the constant apprehensions as to its supply which confront the reader in early literature. The relation between population and its food supply, which left an indelible mark on one period of economic thought, has temporarily, at any rate, retreated into the background with the opening up of new countries, the discovery of new natural forces, and the observed conditions of the more settled nations. Again, so far as England is concerned, the adoption—and for the time, at any rate, the successful adoption—of a Free Trade Policy, led to a lull in the controversies which raged with regard to tariffs, the balance of trade, and protection. Less importance, too, has been attached to difficulties involved in the ownership of the land and the conditions of its cultivation, partly through measures of economic reform, partly, so far as the older and more settled countries are concerned, by reason of the subordination of agricultural interests to the growing and giant industries of manufacture and commerce. Indeed, the only questions which remain conspicuous by reason either of agitation or intrinsic urgency relate to currency, a matter which, however pressing, suffers under the popular disadvantage that its discussion is seen to require actual knowledge, because of its use of technical terms, and one which to all of us is of increasing interest, the economic relations which should exist between the various portions of a widespread empire, with its aspirations after greater cohesion and co-ordinated though distributed strength.

But the very fact that in these respects the various nations differ largely, and that despite these differences the position of the manual labour classes uniformly impresses itself, though perhaps in varying degree, upon the plastic mind of the public, suggests the existence of some positive and active force as a cause for this prominence; and such we find in the alterations in the conditions of labour, which have led naturally, positively and necessarily to a change in the estimation in which it is held.

Though the course of economic development during the past century and a half has differed greatly in various countries, being largely affected both by the particular stage of progress to which they have attained and by the varying relative importance of the two great branches of agriculture and manufacture, a change in the method of employment is common to all. In England this feature is displayed in stronger and more definite relief, less embarrassed than elsewhere by extraneous influences; and it is in England that its nature has been most attentively studied. There the period has been one of undoubted change. The revolution in the methods of industry, of which much has been said, had its counterpart in agriculture, less noticed, perhaps, but hardly less important. While in the former the great mechanical inventions, with the introduction of water and steam power, accelerated the change already in progress from a system of small and local industries to a system of great national industry, the agricultural classes were the witnesses of alterations as vital to their interests, and which were to co-operate in producing a remarkable alteration in the general conditions of employment. Owing partly to improvements in agriculture itself, partly to the sweeping effects of the inclosures

and the abolition of common rights, partly to the greater opportunities afforded for the use of capital by these and other causes, farming came to be carried on in greater separation from proprietorship, and both the average size of farms and of properties would seem to have increased. Agricultural labour became more and more the occupation of a class of agricultural labourers, disassociated from capital and severed more decisively than before from the ownership of the soil, or the prospect of independent cultivation. But this was the very change which took place at much the same time in manufacture. Here, too, the powerful progress of change was sweeping into the distant past the small master craftsman with his one or two apprentices and his three or four journeymen. Here, too, in ever increasing number throng those who are employed with small hope or prospect of ever employing either themselves or others. The development of the means of communication and locomotion, at first by road-making and canalisation, and afterwards by the laying and extension of the vast railway system, set free demand from those bonds of restriction which had confined it to seek its satisfaction in the products of the district, and by delocalising demand localised industry. Here and there, indeed, local industries continued to survive, here and there special circumstances stood in the way of the establishment of factories, but elsewhere and in general there emerged into view the colossal growth of the nineteenth century, the system of Great Industry. And one feature, and that the most important feature so far as we are concerned, in industry as in agriculture, was the demarcation of those engaged into the classes of Employer and Employed.

This tendency to horizontal cleavage, to borrow an expressive term, which may be studied in the contrast between the existing systems and those of the past, as well as in the history of the actual movement, was greatly accentuated by the blurring of those lines of vertical division which had left districts and local groups partially self-subsistent and separate; and, in England and certain other countries, by the disproportionate increase of the urban population, more closely knit and more sensitive to sentiments of union and the possibilities of common action. Non-competing grades have been substituted for non-competing groups. Though these former are more than two, being many in number and capable of extension so far as some degree of non-competition is concerned, there are, however, circumstances inherent in our system which make the separation between the class of manual labour and the others more complete, and restrict within the most rigid limits the competition which can take place. It has been said, indeed, that the leading feature of modern times is the substitution of the cash nexus for the personal nexus, but it may be doubted if it is really the most important. Pecuniary payments connect the employers and those who under the more skilled labour of superintendence control direction and invention, and yet these latter classes rank themselves and are ranked in general estimation with the employers rather than with the employed. They are not included popularly, at any rate, under the term *labour* when labour difficulties are spoken of. We must look somewhat deeper for an explanation. There are some three or four characteristics which may serve to distinguish labour in its popular sense from the other industrial grades.

In the first place, the work is different. Manual labour has to do what is set before it, the others have to devise what is to be done. Their work is one concerned largely with management and with organisation as a whole, and this quality not only enables them to realise the entire circumstances of the industry, but in many cases relieves them from the narrow and unsatisfying consequences of specialisation or restriction to the performance of particular portions of the common task. In the second place, the needs of the manual labour class are particular. Specialisation, and particularly manual specialisation, with its blunting effects on the mind, requires a powerful corrective. In the third place, the highly-skilled labour which directs and invents is less decisively removed from the chance of attaining to the employing class, and even if few prove successful in this to the full extent, the functions they exert are closely akin. It is, no doubt, true that no positive barrier is placed in the way of indefinite rise on the part of those engaged in labour of any kind, however unskilled; but in point of practice the obstacles to be overcome amount well-nigh to prohibition. In the fourth place, the dependence

of several millions of men for their existence on a weekly wage apportioned by others, and dependent on vicissitudes which they not only cannot control, but do not foresee, is a very striking fact. A miserable insecurity attaches to their position. But a weekly or daily wage and uncertainty are ill companions. Rightly or wrongly, the responsibility is attributed to those who pay the wage, and the inculcation of thrift, with all its good effects, only increases the confusion and sharpens the censure. The influences thus described have, no doubt, rarely been operative all to the same effect, and frequently have not been all present at the same time; but shorn though it be, in one case of one, in another case of another, the change which has passed over the lower and more numerous classes of labour is substantially the same. Owing to it labour is subject to the condition of employment by others, and is less responsible in feeling and partly in fact for its own direction, and for the continuance of the means of earning its own maintenance. To the restrictions of society with some reason, and to those who represent to him the restrictive influences without reason, the working man vaguely, if not definitely, attributes want of work, slackness of work, and change of work. Limitations of some kind have always existed, and it would be wrong to ignore the fact that the condition of the classes in question was far worse when these were the incidents of custom and external nature than at present; but then in those cases the limitations on the action of individuals were both inevitable and impersonal. In many ways they seem to have interfered less with the innate conviction on the part of those who were self-employed that failure and success rested on themselves. But now the whole bulk of the nation is employed by others. Another aspect too. People often resign themselves to the inevitable, but they do not recognise the inevitable in the actions and opinions of others.

Moreover, there are other influences besides those purely economic which have added prominence to this important separation into the two classes of Employers and Employed, a very small class of Employers and a very large class of Employed.

The extension of political power and political privileges, which has affected the operative class most of all, has had consequences in more than one direction: men who become voters exercise a greater influence on public opinion and on the opinions of their would-be leaders, than is the case when logic and argument form their only weapons or means of persuasion; and though at times this may take unpleasant forms, in the main it is a perfectly sound political result. People are not made voters in order to act as jurors in an abstract question. They are representative of particular feelings, and are responsible to themselves as to the whole State for bringing into view the interests which are theirs, and the amelioration of which forms part of the problem of government. But even more important in this connection than the influence thus summoned into being for the redress of much that is ill, is the nature of the relation between political equality and social equality. No one nowadays, or, to speak accurately, hardly anyone, believes in the vague and fantastic doctrines which embraced physical and mental equality, as if the time had come for mankind to be cast in one mould, and for identity of condition and accomplishments. But still the extension of political equality may be held to promise something. If not, what can be more vain than the cry for the extended franchise? A vote by itself is no precious possession if we consider it mainly as the right to give abstract decisions on matters of more or less general interest, and as carrying with it no social assurances. Surely a thing such as this would not have formed the motive of the great enthusiasms, and made death itself a thing of nought to those who sought it in tumultuous times. But it is just because it seemed to them to be something more than this that it won its mastery over their life, and because it is taken to be more than this that the more recent extensions of the franchise are so significant. They are construed as rationally involving a greater equalisation, so far as human opportunities are concerned, and as conveying an assurance that there shall not be, so far as society can help it, any one class condemned to bear from generation to generation the burden and toil devolving on the lowest ranks of labour. But whether the feeling be rightly defined, whether it be in itself right or wrong, a belief in such a connection is

powerful in making more conspicuous the subject of Labour, especially the position of Employed Labour.

In another way this subject gains additional prominence, as has been suggested, by the temporary abeyance of other causes of economic embarrassment, and insufficient though this might be as a substantive cause, it is impossible to underrate its effect as subsidiary in the cause of a change already accomplished and capable of attracting more interest with each fresh access of attention bestowed upon it.

But even these do not exhaust the number of subsidiary causes to which so much is due. There are others, and though many of them are comparatively unimportant this is far from being the case with one. The age itself and the character of the age has much to do with the attention, and especially with the sympathetic attention, patiently yielded to the problem. To characterise an age is never easy. It is difficult even when the age is far distant and the human memory so far kind as to refuse to retain more than one or two pieces of information, letting the others slip through and fall into a deep and unrecovered oblivion. How much more difficult when the epoch is our own? But in this instance there are some few features so marked and so capable of identification, that one pauses to ask in amazement if the age of the Renaissance has not dawned upon us again in an altered guise. The resemblance is the more striking if we take the general characteristics and aspect of the two periods as distinct from the particular direction in which the respective movements trend. A renaissance is twofold. On the one hand it is a time of unrest; due, indeed, to the breaking down of old ideals and the decay of former springs of conduct and life, but due also to the magnificent new life quivering to its birth. On the other hand, the meaning of the particular renaissance is to be found in the nature of its own ideals and the fresh direction and impetus imparted to life. Briefly, it is not only a change but a particular change. What the new ideals are and what the new direction, will be determined by the past history and the present needs of the nation passing through its time of stress, and groping blindly after the truth which is to give meaning to its actions, and which it must struggle to express in art and literature and by every means at its command. Analogies between this present period and that of the fifteenth and sixteenth centuries present themselves in different ways. Then, as now, the time was one of discovery, for the great geographical discoveries of the earlier epoch find a counterpart in the scientific discoveries which, like them, have had effects both destructive and constructive; destroying, that is, convictions and opinions resting on certain narrow conceptions of the sphere of life, but giving opportunity on the other hand for new ideas and vaster conceptions. Both are times of a new learning, and though the causes giving rise to the enthusiasm for knowledge may differ, in both cases knowledge has been sought in a return from theories rigid and out of consonance with life to life itself and the facts of life. In the sphere of religion and morals the likeness is strangely evident. In both cases the particular form of religion was found inadequate, in both cases there was failure to distinguish between the fleeting form and the abiding reality, and in both cases there were particular tendencies, largely by way of result, affecting morals and conduct. In the fifteenth century, as now, these latter were not so much in the direction of that coarseness which somehow or other is often called immorality, but rather in that of a lack of moral discrimination and will. Prejudices are to be put on one side, prejudices as to morals, prejudices as to the relations of sexes, prejudices as to one thing and the other. What does it mean? Partly, perhaps, a positive uncertainty—sometimes a pretended uncertainty—as to right and wrong; partly, again, a wanton and curious desire to experiment on all sides and everywhere, to gain emotional experience irrespective of the means and the cost whereby it is gained. Novelty is allowed to cover a multitude of sins. Some such impulse reveals itself in the literature and life of the Renaissance. Do we recognise nothing like it in the present day?

This peculiar moral attitude has its bearing on the subject of our consideration. Each age works out its own salvation. The mediæval Renaissance found its salvation in the emphasis of individuality, alike in religion, in the State, and in

industrial activity. At the present we seem tending in another direction, and in response to our needs and our circumstances seeking a positive moral guidance in an enlarged conception of social duty and solidarity; and the position which employed labour occupies with regard to them is sufficient to insure it attention, and not attention only, but sympathetic attention. Those who have lost their means of faith in the first commandment of the New Testament turn with feverish haste to work out their salvation by a stricter attention to the second, and those whose faith is unimpaired but spiritual vision enlarged perceive that the one is imperfect without the other. Social regeneration, socialisation, collectivism, social duty, social action, are phrases which occur in profusion, and, though they disfigure the language, mark the attitude and give distinction to the actions of the present. In England, at any rate, the imagination of the people has been struck and its feelings stirred with regard to this particular problem, which stands out before other matters sharply marked and conspicuous.

But though it is true that many general influences have combined to increase this prominence, its main and original cause lies in the vast economic change which has swept mankind into two opposite, though not necessarily opposed, classes. To realise the history of that change is a first step towards understanding its nature and its consequences. But for it it would be possible to interpret present complaints as but the repetition of those of the past, and as finding prototypes in the outcries which have arisen from time to time from those who brooded over the contrasts between the poor and the rich. They would mean nothing more than did many an early pamphlet bearing such a title as 'England's Crying Sin with Regard to the Poor.' Or, again, the opposition might be construed as an antagonism between Labour and Capital, in disregard of the union existing between labour of a certain kind and capital, and of the confusion which such a distinction involves between profits and interest.

Of equal importance is the light which history throws upon the present condition of the masses affected by this grave economic change. Its effects might well have been experienced in two ways. Not only did the power of directing their lot pass from them to others, resulting in somewhat subtle consequences as regards the burden and pride of feeling the full responsibility for action, but in addition it would not have seemed unnatural had they experienced considerable material injury from a competition against an employing class with a practical monopoly of capital; and it is true that the conditions of that competition, which, be it remembered, determines the division of the product between wages, profits, and interest, were in one respect altered to their disadvantage. But in another way, and due to the self-same causes, new opportunities were offered for the development of organisations which were to turn the balance in their favour. Till the change of which we have been speaking, till the breaking down of local divisions which held separate those in like circumstances and of like interest in different places, till the simplification into one class of employed of so large a number of those whose means were small, common action for common ends, as, indeed, any definite control and direction by a central authority, were impossible. Thus the very forces occasioning change provided the means for its beneficial regulation. The narrowness of view attributed to a too rigidly specialised labour has been met by educational advantages which, in England at any rate, found their occasion in the factory organisation which began to spread through the country at the close of the eighteenth century. Factory development has given rise to a control which fails of its effect when called on to penetrate into the small workshops and the seats of home industries. Dependence on wages finds a corrective in the growth of benefit societies and the insurance clauses of trade associations; separation from management and capital has in some instances been stayed by schemes for co-operation and profit-sharing; while the greatest defect of all, the weakness of employed labour in competition with the allied and resourceful forces of capital and management, has led to the marvellous organisation of trade unions and kindred associations. In face of these remedial agencies, and despite the mismanagement and abuses which have attended many of them, the ill-fate which seemed at one time to menace the condition of those whose strength lay in

manual exertion has not been realised. On the contrary, these classes have shared to the full in the increased results attending production. According to the most reliable estimates, their condition has undergone not only absolute but relative improvement; and this is due largely, if not altogether, to the opportunities concealed in the bosom of the economic causes which affected employment so ominously. The true remedies are those which arise out of the historical circumstances of the complaint.

The points which have demanded attention are these. Firstly, the causes, primarily economic, which have made labour difficulties so prominent; secondly, the nature of the great economic change resulting in the separation of the labour under employment from that determining and directing industry; and thirdly, the extent to which this has furnished opportunities for the formation of labour associations, and the development of a State policy for regulating the conditions of employment. With regard to the latter point much has been said. It has, for instance, been argued by some that the great modern interdependence of labour of different kinds, the growth of State control, and the supersession in many directions of the private employer by large companies, trusts, and syndicates, are indications of the necessity and possibility of the monopoly and entire management of industry and commerce by the State. But the simplicity of this remedy, which has proved so attractive to many who dwell in a world of ideas as far removed as possible from fact, is an indication of weakness in the eyes of the student of social and historical phenomena. As he examines the varying moods and forces which unite in the tangled complex of modern industry and society, as he traces from their growth the tendencies which have made them what they are, interweaving, counteracting, modifying and coalescing in the pages of history, he grows aware of the intricacies of the economic constitution and mistrustful of simple theories based on the confident recognition of some elements and the neglect, equally confident, of many others. The one-sided solution is no solution at all. Similarly insufficient is the reading which finds a confirmation of unrestricted individualistic competition in the increased social demand for enterprise and individual energy. The careful study of the past two centuries enforces several conclusions as to economic tendencies all of which require recognition. In the first place, with the growth of intricacy and the extension of the area of production and distribution, the free exchange of commodities has become more and more the one effective means of ascertaining what is wanted and what are the requirements of the community. In the second place, so far from there being a diminution, there has been an increase in the urgent need for eliciting and stimulating individual ability. While, in the third place, the necessity for State regulation has been enforced and new opportunities for it provided.

In turning to the *second* matter for consideration, the treatment by economists and in economic writings of Labour and the circumstances of employment, and its results in providing better means of forming correct judgment and judiciously guiding action, will occupy our attention. On the importance, in this respect, of researches into economic history, little need be added. Its value is felt in every direction. Not only does it discountenance premature generalisation based on insufficient, and, if I may use the expression, fleeting data, but it guards us against the still greater danger of first forming conclusions on hypotheses, and then forgetfully assuming that these conclusions are based on observed facts. Viewed more positively, it adds the conception of organic development and furnishes a large share of the knowledge which forms a preliminary to judgment, and which should form a preliminary to social action. But the point to be insisted on here is the enormous recent advance achieved in this direction. Again, the abstract theory of distribution, dealing with the relation between various classes of payments, as rent, profits, interest and wages, has undergone considerable change, owing to the labours of the mathematical school and other economists, who, starting from the qualitative conceptions first prominently employed by Ricardo, have dealt with the inter-relation of these and their connection with value. But by far the most notable progress has been in matters involving quantitative, as well as, or in place of, qualitative admeasurement.

Here rank the elaborate and important researches into the effects produced by alterations in the rate of wages and the hours of labour, into the causes which condition interest and govern its rate, into the effect of royalties and rents in various industries and under varying conditions. While as regards general well-being a vast mass of material has been accumulated, and many careful and suggestive treatises published. We know infinitely more than was known even a short time back about the effect of occupations on health; the character of working-class expenditure and the relation between such expenditure and receipts; the different modes of payment for labour with their respective consequences; the experiments in co-operation, in profit-sharing, in socialism, in communism, in municipal and State management, and other different directions; more about the effect of charity in relation to earnings; about attempts at arbitration, and the like. We have histories of trade unions, of co-operation, of benefit societies, and of other associations depending on working men's efforts for their maintenance in the various industrial countries. The effects of monopolies and partial monopolies resting either on legislative grant or perpetrated in practice have been carefully examined. Modes of trading, with their almost invariable fringe of speculation, have been treated of, with the view of ascertaining their influence on the standard employments of the nations. These are but illustrations, but they are sufficient for the purpose. They point to active growth in Economics in regard to this particular subject. On the other hand, they are painfully insufficient in themselves. We may know more, but we want to know more still. Concurrent with the advance in knowledge, the general conceptions of labour and with reference to its treatment have undergone alteration most marked in three directions. Labour power is no longer viewed as a mere aggregate of hard and disconnected units which can be sifted out or increased under the stress or stimulus of unhindered competition. We recognise that the labour which survives may be so affected in and by reason of the very process of its selection as to be widely different from the forces contemplated and required. In social evolution degeneration, or at any rate variation in the surviving factor, is an almost regular phenomenon. In the second place, the effects of conditions on efficiency have been established in a variety of directions, a matter of peculiar importance when we pass from the contemplation of the working powers available at any given time to questions of their permanence and their future. In the third place, the economic change in the circumstances of employment has served to introduce to the notice of economists the necessity of certain agencies to counterbalance the lack of self-direction and responsibility, agencies, that is, of education and combination.

In view of such and other developments, the great need of the present, apparent nowhere more forcibly than with regard to the matter occupying our attention, is on the one hand the careful modification of the general body of economic reasoning in their light, and, on the other hand, continued close inductive study into the circumstances of both the past and the present. This latter is indeed necessary. To recognise this does not imply any disparagement of other methods required in other stages. In many of the subjects already singled out for notice preliminary deductions have been made and have proved of the highest value. The theory of non-competing groups, the earliest refutation of the wage-fund theory, the theory of the effect upon productivity of altered hours and wages, afford admirable instances of the way in which truths afterwards established on a wide inductive basis were foreshadowed, and an estimate of their importance attempted by writers proceeding along the lines of partial observation and large use of assumption; but these in common with other like attempts must be regarded as preliminary. They do not indicate, for instance, the extent to which the element of which they treat is important. Surely it is just here that we see the necessary relation and mutual importance of the different methods of study which have sometimes been treated as antagonistic. Preliminary and working theories are necessary to the wise conduct of inductive inquiries, but these in their turn are necessary to formulate a theory which may be something more or something other than that which it supplants, which is to be representative in place of being suggestive. But it is a grievous mistake to take the working theory for the necessary

substance, and to assume that the importance of all subsequent researches lies in their connection with it, and that their function is its general verification and further development, whereas they may bring about its actual subversion.

A survey of the results achieved in a particular branch of Economics affords an excellent opportunity for examining the mutual interaction of various methods of study, and their combined progress. The work of the economists of the period extending over the close of last century and the earlier portion of the present one, a period which, as a living economist has well said, has been inaptly and unfortunately termed classical, was mainly occupied in preliminary discussion and in its formulation of theories, some of which dealt with qualitative relations, and many of which must be viewed as working theories only. They dealt, among other matters, with such questions as the connection between the various classes of remuneration and their relation with value, the distinction between utility and material, the causes necessitating payment, and the effect of condition upon the agents of production; but in nearly every one of these respects very much was left for subsequent generations of students to accomplish, and the way for inductive research was but prepared. And much has been accomplished. Theories have been modified, theories have been recast, and new theories have been formulated.

But this gradual advance in study, necessary though it be and common though it is to all sciences and subjects, stands at a peculiar disadvantage in the case of social science, and, to take our particular case, in that of Economics. Here everything is claimed, not only as a working theory for the investigator, but as one for practical people and the statesman, and error is invested with grave, positive consequences. Incorrect theories as to taxation led to the separation between England and those colonies which now form the United States of America; unsound economic and social theories lit throughout Europe the cleansing if devouring fires of the French Revolution; unsound economic theories threatened to sap the vigour of England in the third and fourth decade of the present century, and, to take a specific instance, embodied themselves in the opposition to Factory Reform. This peculiar gravity is at once the difficulty and the importance of economic study. But when the mistakes of Economics, thus sadly illustrated, are cited in its disparagement, does it never occur to those kindly anxious to enforce the salutary lesson, how grave would have been the result had like importance been attached to other sciences in their earlier stages? Have they not had their working theories and made their mistakes? A review of the course of any one of these shows that the difference between such a one and Economics is not in greater immunity from error, but in the degree of importance attaching to the error. This in its turn has its lesson, or rather its lessons. We in this generation have to pay for the wrong attitude assumed in previous times by those who confused working and tentative theories applicable to one time and one place with truths of universal application, proclaiming their belief with a trying absence of misgiving and hesitation. On the other hand, the immense importance of sound economic knowledge, the danger of that which is unsound, coupled with the fact that all legislation and every person must have and will proceed on some economic theory, emphasises the need of stimulating economic research and economic teaching. Other sciences are needed by those training for particular professions; this is needed by all those who, either by action, word, or vote, have a part in the direction of the destinies of a country. It has been suggested with cheap cynicism that differences among economists disprove the utility and need of the study. What a pitiable confusion between the spheres of physical and social science. The majority of men are none the worse in their daily life for a general ignorance of chemistry or biology, but in the case of Economics matters are far otherwise. An average citizen can do and does without a knowledge of theories of chemistry; but some economic theory he will have and some basis for economic action he has or assumes that he has. The only point at issue is whether he should form his opinions after study or in ignorance. Differ though they may on many points of detail and method, economists at any rate will agree in the belief that study is a better

preliminary for economic action than neglect. Knowledge must be sought by the study both of economic method and of economic facts.

The particular question which has occupied our attention illustrates very vividly the great advance made in economic knowledge of recent years. Taken by itself as a type of the general progress which has taken place, a review of its course should serve to reassure those who are tempted in moments of depression to believe that the want of adequate recognition of the study is in some way or other a symptom of its backwardness or failing vitality. The reverse is true. It is the living character of Economics which leads to the demand that its importance should be duly recognised. The advance has been remarkable. The spirit which animates inquiry is as vigorous in the field of Economics as anywhere else. But this much must be remembered. In Economics, as elsewhere, the attainment to anything approaching a perfected theory is very far distant, for a complete theory implies not only full knowledge of facts, but their correct treatment. How distant such a goal is the hardest worker in the field knows best of all, for the circumstances of his inquiries teach him how slow progress is, and how great the continent into which his enthusiasm as a pioneer has enabled him to penetrate some little distance. A few generalisations which may endure, a somewhat mixed mass of material, a brief influence, constitute the work of the foremost. And yet in the history of any science there come times when things move more rapidly than is their wont, as when waters chafing in a narrow passage suddenly burst down all obstacles, and establish themselves once and for ever in a wider channel. It is possible, it seems even probable, that some such moment of advance is before Economics. Materials have been accumulated with singular diligence, critical sagacity has discriminated and classified, and some great constructive advance seems not far distant. The atmosphere of economic thought is instinct with expectation. With a new realisation of the economic elements and motives of society, in the light of some conception perhaps little taken into account as yet, we shall stand nearer to the problem one part of which we strive to unravel—the forces which govern action and constitute society.

The following Papers were read:—

1. *The History of Trade Combination in Canada.* *By* W. H. Moore.

There have been trade monopolies in Canada since the first settlement of the country. The present movement toward trade combination began in the years of depression caused by the low prices of agricultural products and the excessive amount of capital invested in manufacturing industries. The latter, in part, the result of the introduction of a system of high protection. The result of the competition has been destructive, and with the development of machinery the economies which give to a large business an advantage over a small business have had the effect of increasing the size of the factories, mills, and shops, and decreasing the number of producers. The natural end of this destructive competition is monopoly in the hands of one producer. This result has been hastened in some instances by voluntary amalgamations of the businesses of different producers, and in others deferred by a combination of independent producers for the regulation of matters in which they have a common interest. This latter form of union is most common in Canada. The agreements usually contain provisions for the arrangement of uniform price-lists, the diminution of the output, or the division of the market. Combinations of this kind exist, or have existed, in the production or sale of the following goods:—alkali, agricultural tools, biscuits, baking powders, blacklead, blacking, blues, buckwheat flour, building paper, bolts and nuts, barbed wire, binder twine, cigars, cheese (certain brands), cottolene, cocoas, chocolates, condensed coffee, canned salmon, cut nails, coal, canned vegetables and fruits, cotton threads, cordage, dyes, drugs, flour, gelatine, grain, hides, horseshoes, horseshoe nails, ice, lead pipe, linseed oil, matches, oatmeal, petroleum, pickles, prepared

soups, pressed tinware, rope, salt, soaps, starches, spikes, shovels, sugars, tobaccos, varnishes, wire, wire nails.

The manufacture of cotton goods, cigarettes, glass goods, watch cases, agricultural implements, sugar, and other goods, is influenced by the existence of monopolies formed by the union of producers, in which the individual interests are merged in a common undertaking. The rebate plan is the method by which most of the combinations attempt to enforce their objects. It is alleged on behalf of the combination of independent producers, with some degree of truth, that they have developed trade in foreign markets, improved the quality of the goods, and prevented speculation. Against them it is urged they have increased the costs of goods to consumers, and discriminated against the trade interests of certain districts. The 'trust' method is the more economical, and in several instances businesses which were, previous to the formation of the 'trust,' almost bankrupt, have been placed on a paying basis without an advance in the cost of goods to the consumers.

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2. *Recent Aspects of Profit Sharing.*[1] *By* Professor N. P. Gilman, *Meadville Theological School.*

1. The reasonableness of giving a dividend to labour is shown when we consider that human nature is the same in the working man as in the employer. If a share in the variable profits of business is held out as an inducement, the wage-earner will be very apt to take more interest in his work, and will help to make a larger profit than under the usual conditions.

2. Experience has shown that this reasoning is borne out by facts of record. The case of the Bourne Cotton Mills at Fall Run, Mass., was taken to illustrate the working of profit-sharing under unfavourable conditions. In the eight years 1889–97 the Bourne Mills paid bonuses amounting to 54 per cent. on wages, and there was a great improvement in the quantity of the work done.

3. There are now some 120 cases of profit-sharing houses in France, 20 in Germany, 100 in the British Empire, 50 in other parts of Europe, and 30 in the U.S.A., making some 320 in all.

4. This method is not to be recommended as a finality or a panacea, but, as the treasurer of the Bourne Mills says, 'it is worthy of a trial by any fair-minded business man as a modest attempt to improve upon the present wages system.'

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3. *A Consideration of an European Monopoly as a Contribution to the Theory of State Industries. By* S. M. Wickett, *Ph.D., Toronto University.*

The great Austrian tobacco monopoly is the oldest of all existing tobacco monopolies, and as regards the population to which it applies and the number of its employés also the largest. Dating from 1670, it nets the Government at present about 5,000,000*l.* yearly, or 14 per cent. of the total budget.

This form of taxation has become very popular in Europe, for eight out of the seventeen European countries, embracing 38 per cent. of the population of Europe, have incorporated it into their financial system. Financial writers, too, have supported it, *e.g.* Lorenz von Stein, Wagner, Roscher, and Leroy-Beaulieu.

The first point to consider is the effects of concentration on the general conditions of labour. The very satisfactory conditions of labour in the Austrian tobacco factories, notwithstanding the great labour concentration there (on the average 1,181 in each factory); and, on the other hand, the highly unsatisfactory conditions under a system of scattered manufacture, as in Germany, point to the conclusion that a monopoly, in so far as it controls or reforms these latter, confers wide benefits.

As to incentives to an economic administration under State control, the Austro-Hungarian administrative system is suggestive. For by its administrative unification under one central authority—the Ministry of Finance—it excludes

[1] Published in *The Christian Register*, Boston, November 11, 1897.

all undue inter-state competition as to price and as to the quality of the manufactures; but by its divided technical management it preserves a healthy rivalry as to satisfactory conditions of manufacture, and as to financial results to be credited each half of the Empire at the end of the year.

This inter-state or 'federal' monopoly organisation offers a new idea for State activity—control by central authorities, but technical management by provincial officials for provincial credit. Even where the system of provincial credits does not exist, the same principle of organisation will hold good for the general details of manufacture.

As to the effects of the monopoly on export trade there are two features to be considered: the danger of State monopolies being affected in their sales abroad by international relationships, a factor of direct influence on exportation, and seemingly quite overlooked in financial treatises; and secondly, the fact that State monopoly, by increasing home manufacture, renders the question of actual export of relatively small importance. Germany, for instance, for 1893, had a surplus of imports over exports of sixty-one tons; Austria of exports over imports of sixty-seven. And although this year is exceptional, the fact will serve to emphasise the point which the foregoing years have sufficiently shown. This is in direct contradiction to Roscher's opinion, and sets the question of monopoly export in a new light.

With regard to the actual weight of monopoly taxation, the enormous revenues from tobacco would seem to indicate a high rate, that is, a decidedly high price tariff. Austro-Hungary's tobacco revenue for 1893 was 34½ million dollars; Italy's 30 millions, and that of France reached the high figure of 61 millions. Yet everywhere we find cheap tobaccos for the small pocket-book. In Austria in 1893, for instance, 50 per cent. of the cigarettes sold (retail) were at 2 c. per package of ten; 50 per cent. of the monopoly cigars sold (retail) were at ⅗ c. each and under; 54 per cent. of the imported Havanna cigars were at 4⅘ c. each; 73 per cent. of the smoking tobaccos were at 22 grammes for 1 c.

This surprising condition of affairs largely explains itself by savings through avoiding unnecessary competition, and by increased earnings otherwise going to different classes of capitalists (box-makers, lithographers, etc.). And in fact, the actual results of a close comparison of monopoly and competition tobacco prices give results relatively not unfavourable to the former. Monopoly taxation does not appear, therefore, to be at all as high as the large revenues would lead us to suppose.

Finally, as to the question of a progressive indirect tax, a tax said to be possible only under a State monopoly. An investigation of the direction of tobacco consumption under a monopoly shows such a tax to be *primâ facie* improbable, since the consumption tends so strongly to concentrate itself, as indicated, on very few grades, these being, moreover, mainly of the cheaper qualities. On the other hand, these latter qualities, representing machine work, leave a larger tax margin than do the finer qualities consisting mostly of handwork.

The assumption then supporting the possibilities of a progressive rate, viz., that the tobacco consumption will show a gradation as to quality somewhat like the schedules of a progressive income tax, cannot stand. And, on the other hand, given the condition of a large revenue, for the same reasons the tax prices must be set simply according to fiscal principles, that is, according to what each quality will bear—a good principle for fiscal manipulation, not for the realisation of the idealised gradation. In fact, between such a principle and the latter there is no direct connection. And in face of the above-mentioned tendency of the consumption to the cheaper qualities, a progressive rate will be in general possible only under a very low revenue tariff.

These conclusions, the author hopes, will be found to possess a more or less general validity making for a better understanding of the peculiar position of State industries. For fuller details see the author's paper in Schanz's 'Finanz-Archif,' 1897, i., p. 198 *et seq.*

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4. *Statistics of Deaf-Mutism in Canada. By* G. JOHNSON.

FRIDAY, AUGUST 20.

The following Papers were read:—

1. *Some Fallacies in the Theory of the Distribution of Wealth. By* Professor A. T. HADLEY.

2. *Canada and the Silver Question. By* JOHN DAVIDSON, *D.Phil.*

The similarity of conditions existing in the United States and Canada renders it remarkable that while the United States was being convulsed by the movement for free silver, Canada was peacefully conducting an election on a mixed tariff and educational issue. The reason is not to be found in any lack of interest in Canada, but in forces partly political and agricultural, but mainly financial.

Canada has been developed later than the Western States, and in consequence neither has the burden of mortgages been so heavy nor has the fall of prices affected the farmer so seriously. The development of the West has taken place in Canada largely since 1880, and Canadian competition has contributed to the fall in prices.

The political causes of Canada's immunity are partly derived from the constitution which allows the Federal Government a larger field for its activity, because provincial issues can be transferred to the Federal arena; and are partly due to the long period during which one party has held the reins of office. The result of this latter force has been that a not vitally important issue has been kept before the public mind as the universal panacea. As a remedy for depression the Government party has demanded more protection, while the opposition has demanded freer trade.

These, however, are simply contributory causes. The real reason lies in almost perfect adaptation of the banking system of Canada to the needs of a new country, and in the consequent absence of any soft money tradition. The greatest banking necessity in a new country is elasticity in the issues; the greatest danger is that security will be sacrificed to elasticity. The supervision of banking legislation in the colonies by the Imperial authorities, who were devoted adherents of the principles of the Bank Charter Act, prevented the sacrifice of security when the character of the system was being formed, and created a tradition of sound banking which has permitted financial questions to be regarded as problems for experts and not for decision at the polls. Although now the Imperial authorities do and could exercise no supervision, there is an efficient substitute for that supervision in the wide-spread respect for English precedent and example.

The banking system has been a gradual growth, and has by successive amendments been moulded to suit the needs of the community. With almost perfect security there is still such an elasticity in the issues that the volume of the circulation fluctuates in perfect harmony with the fluctuations in the volume of business, not only over long periods but from month to month. The practice of branch banking, which is the most striking characteristic of the system, greatly facilitates this automatic correspondence, besides favouring the development of the newer parts of the country by furnishing them with banking facilities as good as can be obtained in the cities, and equalising the rate of discount throughout the country, and thus providing farmers with capital at practically the same rate as it can be obtained even in the commercial centres, provided they have equally good security to offer.

3. *The Origin of the Dollar. By* Professor W. G. SUMNER.

4. *Silver and Copper in China. By* Dr. J. EDKINS.

5. *Characteristics of Canadian Economic History.* *By* Professor A. Shortt.

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6. *Economic History of Canada.* *By* J. Castell Hopkins.

The author traced the various experimental policies in force through the days of the fur trade and French rule; the period of preferential British tariffs and the colonial restrictions of the Navigation Laws; the effect of the abrogation of the Corn Laws upon Canada; the Reciprocity Treaty of 1854 and the effects of its abrogation in 1866; the period from 1867 to 1872 of a nominal revenue tariff policy which, through extraneous causes, was one of practical protection; the revenue tariff years of 1873–79 in which American manufactures swept Canadian competitors out of their own field; the years of positive protection which followed from then to the present time.

The influences of free-trade and protection, or alternate dependency upon the American market, and upon the British fiscal system, up to the development of Canadian fiscal independence, and the ability to regulate the Dominion tariff in accordance with the wishes of its own people, and in harmony with its obligations to the Empire, were traced at length. Some time was also given to a consideration of the efforts made after confederation in 1867 to obtain reciprocity with the United States.

The conclusion drawn was that Canada's true policy was one of closer commercial relations with the Empire and the steady development of public opinion in favour of a preferential tariff system within its bounds. As to the past, the author believed that Canada had practically run the whole gamut of fiscal experiment and experience, and had tried every form of fiscal arrangement known to theory or practical government.

SATURDAY, AUGUST 21.

The Section did not meet.

MONDAY, AUGUST 23.

The following Papers were read:—

1. *National Policy and International Trade.* *By* Edwin Cannan, *M.A.*

The most widely followed and most generally approved policy in the civilised world is still undoubtedly, as it has been for two or three centuries, the encouragement of exportation and the discouragement of importation. This policy is no longer founded on the idea that it is necessary in order to secure a large stock of the precious metals; that notion is completely obsolete. Nor is it founded on the wish for diversification of industries; this is shown by the popularity of the *Zollverein* idea, which evidently sets no value whatever on local diversification of industries even in an Empire consisting of enormous and scattered territories. Nor, finally, is it founded on the idea of maintaining national security, or the host of other reasons of a particularist, local, and consequently contradictory character alleged by its more ingenious advocates in various countries. Its true source is to be looked for in the fact that exports are supposed to give employment, and imports to take it away, so that encouragement of exports and discouragement of imports tends to increase employment. The usual free-trade answers that exports only balance imports are unsatisfactory, and left a loophole for the entrance of the

pernicious notion that 'artificially cheap' imports, such as the products of prison labour, or of 'bounty-fed trades,' diminish employment. The elementary economic text-books have scarcely furnished any answer since the doctrine that 'industry is limited by capital' was abandoned. The truth of the matter is that industry is limited by labour, *i.e.*, the amount of employment depends on the population. A policy of protection cannot increase population, and consequently employment, except temporarily and under very special circumstances. It is doubtful, however, whether 'increase of employment' has not come to be used in a metaphorical sense, as simply equivalent to increase of pay for the same work. But if this is granted, the protectionist argument falls to pieces, as there was no reason for supposing that the advantages of division of labour cannot be obtained by territorial groups co-operating as well as by groups on other than a territorial basis and by separate individuals.

The true national policy is to take as much advantage of the division of labour as possible. The individual who gets most advantage from it is the one who is able to do the most skilled work in the best way, and the same thing is true of a nation. What statesmen ought to do, therefore, is to aim at improving the finest industrial qualities in the population. There are many ways of promoting this aim, but one of the most important is to allow free importation of the most ingenious and most cheaply produced products of other countries.

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2. *On Public Finance, chiefly in relation to Canada.* *By* J. L. McDougall, *M.A., C.M.G., Auditor-General of Canada.*

Account of the several operations in the receipt and disbursement of public money.

Practically only two sources of revenue—Customs and Excise.

Security for collectors of revenue should not be taken from friends, but from a guarantee company.

All receipts belong to Parliament. No part of them may be paid out without its direct order. Here the directions are given.

Method of preventing officials being governed by routine.

Expenditure.

Advantage of direct connection of Auditor-General's office with Parliament.

Importance of full public accounts.

National Debt.

Expenditure on interest of debt. Two debts cannot be compared accurately by considering the principals alone; you must take into account the rate of interest also.

Excess of Dominion note issue over specie reserve, viz., $12,000,000, costs nothing, but outlay for engraving and redemption.

Proofs that the whole of the debt and more were spent on permanent improvements of a national character.

Mode of separating what is paid for the use of money from what is exacted for the probability of the debtor failing to pay the principal.

Difference between annual interest on our debt due in England and on that of the Imperial Government has decreased between 1874 and 1897 from $1\frac{1}{2}$ per cent. to $\frac{1}{2}$ per cent., making our debts, when they come to be renewed, $183,000,000 instead of $250,000,000, looking to the interest charges.

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3. *Crown Revenues in Lower Canada* (1763–1847). *By* J. A. McLean.

The 'financial difficulties' that arose in the Government of Lower Canada between 1791 and 1841 were not, in the last analysis, financial, but constitutional.

They may be regarded as forming the pounds, shillings, and pence side of the struggle for self-government. The Assembly of Lower Canada, desiring self-government as an end, endeavoured to gain control of the Crown revenues as a means. From 1791 to 1831 these Crown revenues consisted of (1) The casual and territorial revenues; (2) The revenues arising under the Quebec Revenue Act of 1774; (3) A permanent grant of $5,000 made by the Legislature in 1795, to which may be added another small aid, granted in 1801.

In 1831, on the recommendation of the Canada Committee of 1828, the proceeds of the Quebec Revenue Act were surrendered without reserve or condition to the control of the Provincial Legislature. This surrender weakened the Provincial Executive, and encouraged the House of Assembly to hope that constitutional reforms might be obtained by withholding supplies. From October 1832 to the suspension of the Constitution no supplies were voted by the House. In 1836 the Home Government finally decided to apply the provincial moneys to the payment of arrears without the sanction of the Provincial Legislature. Their constitutional weapon being thus wrested from their grasp, the thoughts of a large number of the French Canadians turned towards separation from England, republicanism, independence.

By the Union Act of 1840 the casual and territorial revenues were surrendered with some reservations and conditions to the Provincial Legislature. Most important was the deduction of 75,000*l.* for a Civil List. In 1847, at the request of the Canadian Parliament, the appropriation clauses of the Union Act were repealed, and the Civil List was made to rest upon provincial enactment. Since 1847 all expenditures of the Government have been made under the authority of the Canadian Parliament, consequently, since 1847, it has been necessary for a Canadian Governor-General, entirely apart from his own opinions on the subject of colonial self-government, to choose as his constitutional advisers those who, possessing the confidence of the Lower House, can induce Parliament to vote supplies.

Responsible government became necessary the moment that the Legislature gained full control of the Provincial Treasury. The political situation compelled the solution, and credit is due not only to the great British statesmen who were able to realise the political situation, but also to the great Canadians who created it.

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4. *The Evolution of the Metropolis, and Problems in Metropolitan Government. By* WM. H. HALE, *Ph.D. Brooklyn, N.Y., U.S.A.*

A brief statement is made of the development of Greater New York, otherwise called the city of New York, as it will be constituted on and after January 1, 1898, by the consolidation of the cities of New York, Brooklyn, and Long Island city, the county of Richmond (Staten Island), and a part of the county of Queens. The new consolidated city of New York will be second only to London in population, and will contain a population estimated at 3,430,000, being more than that of the United States when the Government of that country was founded, and greater than that of any other State of the Union at the present time except Pennsylvania, Ohio, and Illinois; or nearly equal to the combined population of the provinces of Ontario and Quebec.

The government of the vast aggregation of heterogeneous elements drawn from all quarters of the globe presents new and difficult problems in American jurisprudence, which the writer hoped would receive elucidation at this meeting.

The charter of Greater New York provides for the novel and interesting experiment of a bi-cameral municipal government, the municipal assembly being composed of two Houses—the common council of twenty-nine members, of whom the president is elected by the city at large, and the other members by districts; and the board of aldermen of sixty-one members, elected one from each district. The mayor of the city has a seat and voice, but no vote in the Upper House, and heads of departments in the Lower.

The reservation to the city of ownership of all public franchises was characterised as the most notable reform in municipal government. The charter limits the term for which such franchises may be leased to individuals to twenty-five years, with renewal for the same period.

The extension of the elective system to all the judiciary was recommended by the writer, in lieu of the system of appointment by the mayor, which is now the case with police justices.

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5. *Local Differences in Discount Rates in the United States.* *By* R. M. Breckenridge, *Ph.D.*

The annexed table of discount statistics for forty-three leading commercial cities of the United States shows:

(*a*) That there is no such regularity or generality in the prevalence of low rates in the large cities, or of high rates in the smaller cities, as to permit the explanation of local differences in discount rates by differences in population between the cities appearing in the reports;

(*b*) That a similar lack of uniformity in the emergence of low rates in towns where clearings are large, and *vice versâ*, prevents the establishment of any close connection between cheap discounts and heavy exchanges, as indicated by clearing returns;

(*c*) That rates of interest upon loans on the security of urban and suburban landed property show a tendency, in their varying heights as between localities generally, though not exactly or always at the same distance, to follow the movements of discount rates;

(*d*) That discount rates appear to be high in proportion as the cities for which they are quoted are remote in western or southern direction from the States on the North Atlantic seaboard of the United States, more particularly from the foremost commercial and financial centres of that region; the cities with heaviest clearings and largest population in each of the other great divisions of the country, in other words, the chief money markets of each section, show, however, somewhat lower rates than places of less consequence in such sections.

Result (*d*) appears more clearly in the following tables.

Cities in the	Show average discount rates for 1893-1896 of from per cent.	Save	Where rates were per cent.
North Atlantic division.[1]	4·046 to 5·800	Buffalo	6·029
		Portland, M.	6·000
South Atlantic division	7·029 „ 8·000	Baltimore	4·685
		Richmond, Va.	6·000
North Central division	6·340 „ 8·000	Cincinnati	5·237
		St. Louis	5·875
		Chicago	5·894
South Central division	6·857 „ 8·427	New Orleans	5·817
		Memphis	6·403
Western division	7·072 „ 10·000	San Francisco	6·230

[1] The several divisions include the following States:—North Atlantic—Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey and Pennsylvania. South Atlantic—Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Florida. North Central—Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska and Kansas. South Central—Kentucky, Tennessee, Alabama, Louisiana, Mississippi, Arkansas, Texas, Okeohama and Indian Territories. Western—Montana, Idaho, Colorado, New Mexico, Utah, Nevada, Arizona, Washington, Oregon and California.

TABLE SHOWING

A. The average Rate of Discount per cent. in forty-three leading commercial cities of the United States for the four years, 1893–96;

B. The same for the years 1893, 1894, 1895 and 1896; compiled from *Bradstreet's*;

C. The rank of the same cities according to population as reported in the eleventh census of the United States, 1890;

D. The rank of the same cities according to the total clearings in each during the year 1896;

E. The total clearings in each of the same cities which had clearing houses in 1896, in millions and tenths of millions;

F. The average rate of interest per cent. on mortgages made upon lots in the counties in which the cities are situate, during the decade 1880–89;

G. The same, during the year 1889.

C	D	E 1896	—	—	A 1893-96	B 1893	B 1894	B 1895	B 1896	F	G
5	2	$ 4.498.1	1	Boston, Mass.	4.046	5.298	2.769	3.206	4.913	5.18	5.03
1	1	28.870.7	2	New York, N.Y.	4.653	6.778	2.904	3.596	5.336	5.40	5.18
6	7	720.0	3	Baltimore, Md.	4.685	6.115	4.625	4.	4.	5.82	5.78
28	25	118.5	4	Hartford, Ct.	4.823	6.106	3.432	3.947	5.807	—	—
3	4	3.161.7	5	Philadelphia, Pa.	4.923	6.115	3.452	4.317	5.807	5.42	5.38
20	16	256.2	6	Providence, R.I.	5.170	6.134	3.817	4.654	6.076	5.78	5.72
8	9	585.8	7	Cincinnati, Ohio	5.237	5.884	4.605	4·846	5.615	6.02	5.95
12	6	745.4	8	Pittsburgh, Pa.	5.800	5.942	5.298	5.961	6.	5.87	5.75
11	11	466.5	9	New Orleans, La.	5.817	7.038	4.98	4.75	6.50	7.28	7.13
4	5	1.158.6	10	St. Louis, Mo.	5,875	6.634	5.404	5.250	6.211	6.21	5.92
2	3	4.413.0	11	Chicago, Ill.	5.894	6.452	5.240	5.336	6.548	6.43	6.33
36	30	66.0	12	Portland, Me.	6.	6.	6.	6.	6.	—	—
23	26	114.1	—	Richmond, Va.	6.	6.	6.	6.	6.	—	—
10	19	219·3	13	Buffalo, N.Y.	6.029	6.115	6.	6.	6.	5.75	5.73
7	8	684.9	14	San Francisco, Cal.	6.230	7.115	5.807	6.	6.	6.88	6.61
14	17	230.8	15	Milwaukee, Wis.	6.340	6.977	6.115	6.	6.269	6.32	6.19
26	27	104.6	16	Memphis, Tenn.	6.403	8.	5.98	5.384	6.25	—	—
22	21	204.1	17	Indianopolis, Ind.	6.461	7.153	6.692	6.	6.	6.38	6.23
9	14	299.3	18	Cleveland, Ohio	6.471	7.	6.884	6.	6.	6.37	6.24
13	13	300.1	19	Detroit, Mich.	6.519	7.	6.230	6.	6.846	6.76	6.64
16	15	286.3	20	Louisville, Ky.	6.857	7.066	6.596	6.788	6.980	6.01	5.93
24	34	29.9	21	Nashville, Tenn.	6.903	8.	7·653	5.961	6.	—	—
18	18	228.8	22	St. Paul, Minn.	6.913	7.615	7·692	6.	6.346	7.37	7.07
19	10	503.7	23	Kansas City, Mo.	6.988	6.913	6.269	6.769	8.	7.68	7.22
27	—	—	24	Charleston, S. Ca.	7.029	7.115	7.	7.	7.	—	—
30	33	57.2	25	Los Angeles, Cal.	7.072	7.288	7.	7.	7.	—	—
15	12	392.9	26	Minneapolis, Minn.	7.077	7.577	6.980	6.5	7.250	7.47	7.04
40	—	—	27	Galveston, Texas	7.139	7.019	7.	7.	7.538	—	—
29	32	62.4	28	St. Joseph, Mo.	7.221	6.884	7.	7.	8.	—	—
38	—	—	29	Duluth, Minn.	7.341	7.961	7.019	7.	7.384	—	—
39	—	—	30	Mobile, Ala.	7.697	6.788	8.	8.	8.	—	—
17	20	210.8	31	Omaha, Neb.	8.	8.	8.	8.	8.	7.71	7.28
25	28	69.0	—	Atlanta, Ga.	8.	8.	8.	8.	8.	—	—
33	23	124.7	—	Savannah, Ga.	8.	8.	8.	8.	8.	—	—
42	37	20.6	—	Birmingham, Ala.	8.	8.	8.	8.	8.	—	—
41	—	—	—	Houston, Texas	8.	8.	8.	8.	8.	—	—
43	—	—	—	Little Rock, Ark.	8.	8.	8.	8.	8.	—	—
31	31	62.6	—	Portland, Ore.	8.	8.	8.	8.	8.	—	—
32	29	68.5	32	Salt Lake City, Utah	8.234	8.	8.038	9.	8.	—	—
35	22	131.7	33	Dallas, Texas	8.427	8.788	7.576	8.423	8.923	—	—
37	36	27.0	34	Tacoma, Wash.	9.341	10.	9.365	10.	10.	—	—
21	24	121.3	35	Denver, Col.	10.	10.	10.	10.	10.	8.34	7.71
34	35	27.9	36	Seattle, Wash.	10.	10.	10.	10.	10.	—	—

It is believed that such extraordinary local differences are not explained, (*a*) by the 'disinclination of capital to migrate,' as considerable movements of loanable capital occur as the result of arbitrage business between the foremost money markets of various European States and of the United States, with a much smaller difference in prospective return as the sole inducement; nor (*b*) by the difference in the security of the paper offered for discount on the markets of the various cities considered, as the averages have, in all cases, been calculated

from the lowest rate quoted weekly for such cities, and may consequently be held to represent the price paid for discount of the best paper which was made in those localities.

Differences in the rate of discount charged upon the best paper brought to market so greatly to the disadvantage of districts remote from the chief money markets of the land, do not emerge in countries where a number of large banks extend their activity into every considerable district by means of numerous branches and agencies, *e.g.*, as in Scotland and Canada; nor where a great central bank, in observance either of the law or of its own interest, provides identical facilities to discount customers in every market of consignment, *e.g.*, as in France, Germany, Austria, the Netherlands, Belgium and Japan.

It is submitted, therefore, that differences in discount rates as between the various cities and geographical divisions of the United States are chiefly to be explained by the peculiarities of the banking system of that country. It consists of nine thousand odd 'National,' 'States' and private banks, each confined in the main to one locality, and the neighbourhood immediately thereto adjacent, as well in its borrowing as in its lending business. But 3,600 banks, in round numbers, enjoy privileges of issue, and these are extremely restricted in character. Just as there exists no adequate machinery for gathering up loanable capital from the older and accumulating groups of the population and applying it further west and south, to the exploitation of natural resources and of other undertakings, the development of which is in progress, or awaits the beginning, so is there no efficient system of domestic arbitrage, nor even an approximate equalisation of discount rates.

TUESDAY, AUGUST 24.

The following Papers were read:—

1. *The Economic Geography of Rhodesia.* *By* F. C. Selous.

(Joint meeting with Section E. See p. 721.)

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2. *Economic Aspects of the Workmen's Compensation Bill.* *By* J. R. Macdonald.

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3. *The Relation of the Employment of Women and Children to that of Men.* *By* Carroll D. Wright.

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4. *Recent Reaction from Economic Freedom in the United States.* *By* R. R. Bowker.

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5. *The Theory of Economic Choices.* *By* Professor F. H. Giddings.

WEDNESDAY, AUGUST 25.

The following Papers were read:—

1. *Some Economic Notes on Gold Mining in Canada.* *By* Professor J. Mavor.

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2. *Theory of Railway Rates.* *By* W. M. Ackworth.

Section G.—MECHANICAL SCIENCE.

President of the Section—G. F. Deacon, M.Inst.C.E.

THURSDAY, AUGUST 19.

The President delivered the following address:—

In this ever-memorable year of the Victorian Age, it is not unnatural that anyone called to fill the chair I occupy to-day should experience a sense of oppression, when contemplating the fruits of mechanical science during the last sixty years, and the tremendous vista, fading in the distance to a dream, of the fruits it is destined to produce before such another period shall have passed away.

There would be no possibility, in the time at my disposal, even if I were qualified to attempt it, of adequately reviewing the past; and however fascinating the thought may be, it would ill become my office to venture far along the vista before us, lest a too airy imagination should break the bonds of that knowledge and that truth to which she must ever remain, in our rightful speculations, a helpful, if not always an obedient, handmaiden.

In the year 1831, two places, the one ancient and memorable, the other young, but destined to become memorable, bore the name of York. At the first of these, amid relics of ancient Rome and lasting memorials of the better phases of Britain's mediæval history, were met together in that year the earliest members of the British Association. And as the sun at noonday shone on that ancient York, it rose upon the other York—a little town, scarcely more than a village, of 1,700 people, fast springing from a plain on the shores of Ontario, where the wigwam of the Chippewa had lately been; and between the two lay the Atlantic and a distance of 3,800 miles.

Sixty-six years later, the British Association meets in that other York, distinguished under the name of Toronto, and grown into a noble city. Painfully, in stage coaches, must many of the founders of this Association have travelled to that ancient York; peacefully and amid all comfort and luxury have we from the mother country reached, at her invitation, this great city—chiefest, in her people, her commerce, and her University, of the cities of Western Canada.

Neither at the meeting in York of 1831, nor elsewhere, until many years later, was there any expectation of the possibility of these things. Six years later, about the beginning of that glorious reign of which the sixty-first year is now passing—although two or three vessels had already crossed the Atlantic under steam, it was still seriously doubted whether, without the aid of a Government subsidy of considerable amount, a line of steamers, even for the New York service, could be permanently maintained. It was not, indeed, until 1838 that the *Great Western* inaugurated the attempt on a commercial basis, and she performed in fifteen days the voyage which is now regularly performed with complete commercial success in five.

Would not the suggestion of such a change, of such a spanning of great distances, of such a consequent growth of prosperity and of culture, within the reign of a princess then approaching womanhood, have been received as the wildest of forecasts by the British Association of 1831?

Yet this is but one of a multitude of results, no less startling, which the same agencies have brought about. We are now holding the second meeting of the Association in Canada, and at the first such meeting, held thirteen years ago in Montreal, some hundreds of miles nearer home, Sir Frederick Bramwell told you from this chair, in his own inimitable way, the causes of so great a change, and he pointed out to you, as I venture to point out again, that the visible instruments of that change have been forged by the men who are, or were, or ought to be, the members of Section G. To such encouragement as Section G has given is largely due the progress and triumph of applied mechanics as the natural outcome of theoretical investigation and physical research. Finally, and with no reserve in the minds of reasonable men. the old fallacy of a discord between theory and practice has been swept away. For centuries that fallacy held apart, as it were, the oxygen and the nitrogen of that atmosphere in which alone the new life could exist. It limited the philosopher who examined the laws of nature almost entirely to the study of phenomena external to the earth on which he dwelt, and it stamped the practical man as a lower being, the possessor of certain necessary knowledge, having no relation to the studies of the schoolmen, and which it would be beneath their dignity to pursue. And notwithstanding the great names which have stood out in opposition to these views, the popular idea of discord between theory and practice took long to die, and only within the Victorian Age has the complete truth been generally recognised, that if one fails to account for the result of any physical combination, the cause is to be found not in any discord with theory, but in the fact that the observer has failed to discover the whole of the theory.

We English-speaking people, alone, I believe, among civilised nations, use this word, *theory*, with unpardonable looseness—as almost synonymous in effect with *hypothesis*, and the result is fruitful of error. Until the truth of any hypothesis is placed beyond all manner of doubt it is not, and should never be called, the theory.

Within these walls, the *genius loci* impels me to thoughts which have not often entered into discussions of Section G; and, perhaps, if this address were to be discussed, I should choose subjects and premises, the proof of which, to the satisfaction of others than myself, it would probably be less difficult to maintain. In this University of Toronto under whose *ægis* all that was best in the older schools of thought is cultivated by the side of those practical applications of science which in bygone days were distinguished as the unworthy uses of philosophy, one's thoughts insensibly turn to the marvellous change in the opportunities afforded for acquiring a knowledge of applied science—for beginning, in short, the career of an engineer.

It is not proposed to discuss the progress and prosperity which mechanical science has brought about in the Victorian Era, much less that which the succeeding years will yield; but I venture to think that a proper subject for consideration from this chair, if not for discussion in this Section, is to be found in any unnecessary waste of energy which may occur in the process of mental development of the men who are to succeed us in the great work to which we devote our lives. Obviously it is to the interests of our calling, and consequently of the nation at large, that such waste should be reduced to a minimum, and therefore I make no apology for mentioning certain points in which its presence is particularly striking. There may be waste of potential, as well as of actual energy, and if we fail to expend energy on certain subjects because our time is occupied with others which are less useful, it is waste of energy only differing in degree from its expenditure on useless subjects. There is assuredly no lack of potential energy in the coming race. In spite of any training, whether well or ill directed, a large proportion will become actual and useful energy; but guidance and direction being given, the mode of that guidance and direction should be the one best calculated to secure the highest possible proportion of useful effect.

If we look back at the greatest names among the engineers and inventors of the latter part of the eighteenth century and the first half of this, we find that the majority were brought up in pursuits quite distinct from the work of their after lives, and by which they have become so familiar to us. There were scarcely any means whatever, beyond the original thought and dogged perseverance of the worker, by which those men could attain the knowledge they used with such effect. Men of no less exceptional parts are among us now, but the whole environment of their early work has changed. We have given to the exceptional man a starting-point of knowledge which, wisely used, lifts him as high above our heads as of old, but we have given to the average man a comparatively easy means of attaining the same knowledge. We cannot ensure the wise use of that knowledge, but we can at least endeavour to impart it in such a manner that the sense of right proportion shall be acquired and maintained. We have made it more difficult to distinguish between the exceptional and the commonplace—between the gold and the silver, if not between the silver and the brass; let us be careful, so far as early guidance can control it, that the knowledge imparted to the average mind gives to that mind a fair start concerning the relations, undivided and indivisible, between true theory and sound practice.

Having myself passed as an ordinary apprentice through workshops of mechanical engineering in the old days when working hours were longer than they now are—from six in the morning till six in the evening, and that, too, on the banks of the Clyde, where no special indulgence was given to what was sometimes called the 'gentleman apprentice,' and feeling convinced, as I still do, of the immense and permanent advantage derived from that experience, I shall not be judged to underrate its value in the case of others who have yet to choose the details of the career by which they expect to gain a place in the profession or business of an engineer.

On the other hand, as a student thirty-four years ago under the late Professor Macquorn Rankine and the present Lord Kelvin, I shall not be prone to underestimate the advantages of academical training in its proper application to the profession to which I am proud to belong.

In the pursuit of that profession it has fallen to my lot to observe the training as engineers of many younger men—men of variously constituted minds, but one and all bent on learning some portion of 'the art of directing the great sources of power in nature for the use and convenience of man,' words wisely chosen, sixty-nine years ago, and set out as the object of the profession in the Royal Charter of the Institution of Civil Engineers. It is a noble object, this *direction of the great forces of nature for the use and convenience of man*; it is an ambitious object, and one which I venture to think demands for its right performance the best energies of well-balanced minds working upon a store of knowledge which nothing but years of untiring study and observation can give. Yet there is no hesitation shown to enter the lists. The number of candidates is appalling. In the old country, at least, there certainly is not work for all, but when one points this out, anxious parents only reply that the difficulty is as great in connection with any other profession. Whether this be so or not I cannot judge, but I am persuaded that of those who do enter the business or profession of the engineer, the enormous majority are not born engineers, and cannot, in the nature of things, hope for success unless they take advantage of the best facilities open to them—the *best facilities*; here is the difficulty: from the multitude of facilities how are we to choose?

Do not suppose that I think the training of the born engineer should not be controlled. He will stand head and shoulders above the rest of us whatever we may do with him; but in order that his exceptional parts may not wreck him as an engineer, and in order that his energies may be rightly directed at the start, he, too, should have the advantages of that systematic training which to his less gifted brethren is becoming more and more absolutely essential to success.

At the time I began practice the large majority of young engineers were left entirely to their own devices so far as the attainment of any scientific knowledge was concerned. As pupils or apprentices, articled or not, they entered an engineer's works or office; for a certain number of years they had the run of the place and

some encouragement if they worked well, but it could not, in the nature of things, amount to much more. This was a very necessary, perhaps the most necessary, element of their training; but except to the few who were so constituted that with little or no guidance they could supplement their practical knowledge with the study of principles elsewhere, it was entirely ineffectual in the production of that well-balanced attitude of mind which any person who properly assumes the name of an engineer must hold towards every engineering problem, great or small, which he is called upon to solve. And so strongly have I felt this, that in the earlier days, when there were fewer schools of practical science, and when their utility was little understood, I required, wherever the matter was under my control, the insertion into the articles of apprenticeship of a clause by which, at some inconvenience to the office, the pupil was required to attend two sessions at the science classes of Glasgow University, or at some other approved school of practical science; and without this condition I declined to take the responsibility attaching to the introduction into the profession of men who, in their earlier careers, from no fault of their own, had not even acquired a knowledge of what there was to learn, much less of how to learn it.

More recently this course has generally become unnecessary; for in Westminster, at least, the young engineer rarely enters an office until he has acquired some knowledge of what he has to learn. He enters, in short, at a much more advanced age than formerly. When it is essential that he should be earning something soon after he comes of age, anything like a complete training is an impossibility; his work ceases to be general, and his practice is more or less confined in a much narrower sphere than need be the case if the pursuit of further knowledge continues to be his chief duty.

But whatever course his circumstances may permit him to adopt, the difficulty of gaining the required knowledge in the time available is a serious one. This is not the place to inquire whether public school education in the mother country is, or is not, the best for the general purposes of after life, or to discuss what improvements may be made in it; and of higher education in Canada I unfortunately know little or nothing. Personally I admit the possibility of improvement in the English system, and slowly but surely improvement is creeping in, as such changes rightly find their way into institutions which have done so much for Englishmen. In this particular I lean to the conservative side, and whatever our individual views may be concerning the time spent on the study of Latin and Greek, we should all probably agree that the school education of an engineer should be as thorough and liberal as for any other profession. But for the sake of a technical training to follow, this school education is often unduly curtailed, to the great after-grief, in very many cases, of the successful engineer, and not infrequently also of the less successful engineer who, in some phases of his professional career, has been only too keenly alive to the self-reproach and sense of inferiority which want of thoroughness or of time, or of both, at school has brought upon him.

But at some time the boy must leave school. Let us hope that he does not aspire 'to control the great forces of nature'; but if he does we must make the best we can of him.

It is not desirable, at least so it appears to me, that even at this stage his training should be specialised in view of the particular branch of the profession or business he is likely to follow. The fundamental principles of any branch of mechanical engineering are broadly the fundamental principles of any branch of the profession. I hesitate to speak of civil engineering as if it were a separate branch, instead of being, as it really is, the generic name of the profession; but the training demanded for the various branches of civil engineering in its narrower sense is precisely the same as that required in its earlier stages for mechanical engineering pure and simple.

I shall make no attempt to review the large number of excellent courses which are now available for the teaching of applied science in relation to engineering. Experience of the results as judged by the students who have come directly under my notice, and examination of many calendars, has aroused various thoughts con-

cerning them, and this thought is perhaps uppermost: *are we not in some cases attempting at too early a stage the teaching of subjects instead of principles?* Complete subjects, I mean, including the practical working of details which will become the regular study of the student in the office or works of an engineer. It certainly seems to me to be so. I do not say that subject training of this kind at college may not be useful; but we have to consider whether it does not, for the sake of some little anticipation of his office work, divert the attention of the student from the better mastery of those principles which it is so essential for him to grasp at the earliest possible time, and which do not limit his choice in the battle of life to any branch whatever of the profession or business of an engineer, but which, on the contrary, qualify him better to pursue with success whatever branches his inclination or his opportunities or his means may suggest. Not one in a hundred of us can hope to emulate the careers of exceptional men in our profession, but it is sometimes useful to observe those careers, and whenever we do so we find the very reverse of specialisation. The minds of such men are impregnated with the fundamental principles which we may call the common law of our art; it has happened that their practice has been large in certain branches, and small or wanting in certain others; but in any it would have been equally successful. Of no class of men can it be said with greater truth than of engineers that their standard should be sound knowledge of the principles of many things and of the practice of a few.

There is some danger in the usual limitation of compulsory subjects in examinations for certificates and degrees. When an examination has to be passed subjects not made compulsory are too often entirely neglected, however important to the engineer they may be. A little learning is certainly not a dangerous thing if within its limits it is sound, and every engineer will in after life be grateful to those who in his student days insisted upon his acquiring some knowledge of the principles of such subjects as electricity and chemistry. At present it too often happens that, unless an engineering student is predestined to practise electrical work or some chemical industry, he begins life as an engineer with little or no knowledge of the principles of either the one or the other, and chiefly as a result of their neglect for the sake of certain subjects made compulsory for the test he has had to pass, which subjects too often include highly specialised details which, I venture to think, cannot be rightly mastered in schools. It is natural and right that each professor of a principal subject should seek to make the best, from his own particular standpoint, of every student who attends his lectures or his laboratories; and the professor of a compulsory subject cannot be expected to encourage the inclusion, in a course already overcrowded, of secondary or collateral subjects which are dealt with by other professors; while, on the other hand, the professors of secondary subjects, such as electricity or chemistry, not unnaturally value chiefly the students who make those subjects their principal work.

For these reasons it appears to me that a certain very moderate standard in all such subjects should be made compulsory if a certificate of proficiency, whether by degree or otherwise, is to be given to students of engineering.

In the teaching of mathematics within the Victorian age a considerable change has taken place, and I plead for still a little more change in the same direction where the training of the engineer is concerned. Mathematics, as taught in our public schools—let us say for the Cambridge University Tripos—may be all that is claimed for it as a mode of mental culture; but of kindred mental culture the engineer must necessarily have more than most men, and much might therefore be omitted which, to him at least, has only an abstract value, to the great advantage of his mastery over those branches which at once train his mind and give point and direct utility to his solutions.

In America I understand that a college course of engineering generally includes workshop practice designed to supersede the old system of apprenticeship to a mechanical engineer. This fact and other important differences between the English and American practice have only lately come to my knowledge, and before they did so the substance of this address had been written. It might, in some particulars, require modification as applied to Canada, but it remains the result of

my observations concerning the conditions of engineering education which obtain in the mother country.

A few words now in relation to that physical and mental training gained laboriously, and somewhat wastefully as I think, at the joiner's bench, in the fitting and turning shops, the foundry and the forge, during the old course of mechanical engineering apprenticeship. I am convinced that the kind of knowledge which comes of thoughtful chipping and filing and turning and forging, though only applied to a few of the materials with which in after life the engineer has to deal, are quite as important as tables of density and strength to his future sense of rightness in constructive design. The use of such work is not merely to teach one the parts and combinations of any particular machine; in a still higher degree it is the insensible mastery of a much more subtle knowledge or mental power, the application of the senses of sight and touch and force, it may be of other senses also, to the determination of the nature of things. (I am not going to apologise for referring to the *sense of force*. The vexed question of its separate existence appears to me to have been settled fourteen years ago by Lord Kelvin in his address at Birmingham on 'the six gateways of knowledge,' and I may well leave it where he left it.) I should altogether fail to describe adequately what this mastery means. It appears to me to be inscrutable. The value and nature of the power can only be appreciated by those who have experienced it, and who have felt its defect in those of their assistants or in others who do not possess it.

But the great workshop training has still further advantages. The apprentice is surrounded by skilled workers from whose example, if he is wise, he learns a great deal; and apart from this it is no small profit to have rubbed against the British workman, to have discovered what manner of man he is, and to comprehend how little the world knows of his best parts. The whole time spent in large engineering works cannot, however, be uniformly beneficial; the apprentice must take the work as it comes; the most interesting or instructive portions cannot be reserved for him, and he often feels that some of his time is being well-nigh wasted.

A few years ago I should not have thought it practicable usefully to substitute for such a course anything that could be undertaken in a student's workshop, however organised; but the impossibility, in many cases, of including such experience without neglecting something equally important has led me to view with satisfaction the introduction of workshop training into certain schools of applied science in England. Such a change cannot of course carry with it all the advantages of experience in the great workshop and of contact with its workers, but those advantages which it does retain may be secured in a shorter time where there is no commercial interest to be served.

In Canada and the United States, as I have already said, the principle of the student's workshop has been carried considerably further. Compared with the old country, I believe the number of young assistant engineers who in proportion to the number of their chiefs can find employment in America is much greater, and that it would be practically impossible for the British system of pupilage to be generally employed. Here, therefore, the whole college training of an engineer is designed to fit him for immediate employment in some specific branch of the profession, and up to this point his training is, necessarily no doubt, more academic than in England, where the application of the principles he has acquired at college is still generally left for the office or works of the engineer. With this difference I am not at present concerned, but I desire to reiterate what I have already said to the effect that where, as in England, the student of engineering has the opportunity of continuing his training in the office or works, it is better that his limited college course should cover all that is possible of the principles of those sciences which may prove useful or necessary to him in after life, rather than that any of them should be omitted for the sake of anticipating the practical application of certain others.

The compulsory inclusion of the principles of all such subjects as chemistry, electricity, geology, and many others, in science courses intended for a future engineer is desirable not only because a fundamental knowledge of them leaves

open a very much wider field from which the engineer may, as opportunity offers, increase his knowledge and practice in the future, but because many of such subjects are inseparable from an intelligent understanding of almost any great engineering work. 'Nothing so difficult as a beginning' may be a proverb of rather too far-reaching a nature, but it contains the suggestion of a great truth, increasing in weight as we grow older, and the beginnings of such collateral sciences should therefore find a place in every engineering student's store of early knowledge.

But after all, when these things have been done in the best manner—when the scientific and practical training of the engineering student has been all that can be desired, it is a matter of general experience among engineers who have closely watched the rising generation that the most successful men in after life are not produced exclusively from the ranks of those whose college course has been most successful. No doubt such men have on the average been nearer the top than the bottom, but it is an undoubted fact that when we class them according to their earlier successes or failures we find the most remarkable disparities. We find many who in academic days gave but little promise, and we miss large numbers who promised great things. These facts are not confined to the profession of the engineer, but they seem to me to be accentuated in that profession. We shall no doubt be right in attributing the disparity to differences of mental temperament and of opportunity; but does it follow that there are no faculties which may be cultivated to reduce the effect of such differences? I venture to think there are. I will instance only one, but perhaps the most important of such faculties, and which in my experience among young engineers is exceptionally rare. I refer to the power of marshalling facts, and so thinking, or speaking, or writing of them that each maintains its due significance and value.

In the minds of many young engineers exceptional mathematical powers often have the effect of making it extremely difficult to avoid spending an amount of time upon some issues out of all proportion to their importance; while other issues which do not readily lend themselves to mathematical treatment, but which are many times more important, are taken for granted upon utterly insufficient data, and chiefly because they cannot be treated by any process of calculation. I believe that nothing but well-directed observation and long experience can enable one to assign to each part of a large engineering problem its due importance; but much may be done in early training also, and I think ought to be done, to lead the mind in broader lines, to accustom it to look all round the problem, and to control the imagination or the natural predilection for one phase from disguising the real importance of others. In the practical design and execution of important works the man will sooner or later be recognised who has the power so to formulate his knowledge, and on the same principles has succeeded in so marshalling and expressing his thoughts, as to convey to those by whom he is employed just so much as may be necessary and proper for their use.

Such considerations are not, it is true, a branch of mechanical science, but being essentially important to the attainment of maximum usefulness in the application of any science to the various branches of engineering which are the chief ends and aims of mechanical science, they are, I think, worthy of mention from this chair.

In proportion as the engineer possesses and exercises such powers he will avoid those innumerable pitfalls to which imperfectly instructed ingenuity is so particularly liable, and to which the Patent Office is so sad a witness; and in the same proportion must always be the useful outcome of the great schools of science which have become so striking a feature of the later Victorian age.

In relation to the results of applied science, I have spoken only of the steamship; add the telegraph, and I think we have the most important tools by which the present conditions of modern civilisation have been rendered possible. And more than this, I think we have, in the lessening of space, and the facility for intercourse they give, the chief secret of that marvellous development of the empire which this year has so pleasantly and so memorably signalised. Is 'Our

Lady of' the Sunshine and 'the Snows' no nearer to the mother land than sixty years ago? Are the Australias—New Zealand—no nearer to both? Assuredly they are. Would British Africa, would the Indian Empire have been possible to Britain on the principles and the methods of Imperial Rome? Unquestionably not. Then let me say again that I claim for the objects and the work of Section G a magnificent record, an abiding power for the peace of the world, and for the unity and prosperity of the great empire to which we belong.

The following Papers were read:—

1. *The Soulanges Canal, a Typical Link of the* 14*-foot Inland Navigation of Canada between Lake Erie and Montreal. By* J. MONRO, *M.Inst.C.E.*

The paper contained a short history of canal construction in Canada from its beginning in 1779, under General Haldimand, to the present time. Also some remarks on the growth of population and commerce, together with a comparison of the chief characteristics of the rival routes for the western trade; and the reasons why it is probable that the St. Lawrence will eventually obtain a large share of it.

This was followed by a description of the Soulanges Canal—its location—together with the various modifications introduced into its construction and by which it is believed navigation for large propellers and consorts will be rendered safer and more expeditious than heretofore.

The paper was accompanied by maps, plans, and photos, illustrative of the subject.

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2. *On the Hydraulic Laboratory of McGill University. By* Professor HENRY T. BOVEY, *M.Inst.C.E., and* J. T. FARMER, *Ma.E.*

This paper commenced with a general description of the equipment in the Hydraulic Laboratory, McGill University, Montreal, and then discussed in detail the principal pieces of apparatus. Amongst these, especial reference was made to the following:—

The *valve arrangement* in the experimental tank by which the orifice plates can be easily taken out and replaced by others, with the loss of not more than a pint of water, whatever the head over the orifice might be.

A *jet-measurer*, by which the sectional dimensions of a jet at any point of its path can be rapidly and accurately determined.

An *impact* machine for measuring the force with which water issuing from orifice nozzles or pipes strikes buckets or vanes of different forms and sizes.

A *pressure* chamber which defines more accurately the mean pressure at any point of a mass of water flowing through a pipe. The main feature of this chamber is the substitution for the small holes usually adopted of a continuous opening less than ·005 inch in width, around the bore.

A *self-adjusting dynamometer* giving the drag in a single reading. One half of the brake-band is of leather and one half of copper, the angle of contact for each material being very approximately 180°. The frictional resistance of the leather is greater than that of the copper. Thus, if the band friction should increase, the drag would also increase, a portion of the leather would be unwrapped, an equal portion of the copper would be brought into contact so that the frictional resistance would be less, and the drag would continue to diminish until dynamical equilibrium had again been established. If the band-friction should diminish, a reverse process would be the result.

A triple-throw single-acting *experimental pump*, designed for a maximum speed of 150 revolutions per minute against a pressure of 120 lb. per square inch. The pump has interchangeable valves, and is also provided with a specially designed

continuous triple indicator apparatus which autographically records during a trial the speed, variation, and duration of the valve chamber pressure at any point of the stroke.

FRIDAY, AUGUST 20.

The following Report and Papers were read :—

1. *Supplementary Report on the Calibration of Instruments in Engineering Laboratories.*—See Reports, p. 424.

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2. *The Strength of Columns. By* Professor GAETANO LANZA.

An attempt to compute the strength of any given column by the various rules and formulæ commonly found in different handbooks, and books written by so-called authorities, will speedily reveal considerable discrepancies, not only in the formulæ, but also in the results.

Hence it becomes a matter of importance to make a careful study of the tests that have been made, under practical conditions, on columns of such sizes and proportions as are used in construction; for, whether we desire to adopt empirical formulæ or to endeavour to obtain rational ones, the final tests of all theories and formulæ must be whether they agree with the facts as shown by the results of such tests.

A summary is therefore given of the principal experiments that have been made of columns of practical sizes.

The greater part of the tests contained in this list were made on the United States testing machine of eight hundred thousand pounds capacity, located at the arsenal at Watertown, Massachusetts. The details of these tests are published in special yearly reports issued by the Ordnance Department of the United States Government.

The following is the summary :—

Cast-iron Columns.

1. Tests of Metals, Watertown Arsenal, Reports of 1887 and 1888.
2. Bauschinger, 'Mittheilungen aus dem Königl. Mech. Tech. Lab., München,' Heft 12, 1885, and Heft 15, 1887.

The Watertown reports contain tests of eleven old and of five new cast-iron mill columns.

Bauschinger tested the relative ability of cast and of wrought iron columns to hold their otherwise safe load when heated to redness and sprinkled with cold water.

Wrought-iron Columns.

1. Bouscaren, 'Report of Progress of Work on the Cincinnati Southern Railway,' 1875.
2. 'Transactions Am. Soc. Civil Engineers,' 1882.
3. 'Transactions Am. Soc. Civil Engineers,' 1884.
4. 'Exec. Doc. 12,' 47th Congress, 1st Session, House.
5. 'Exec. Doc. 1,' 47th Congress, 2nd Session, Senate.
6. 'Exec. Doc. 5,' 48th Congress, 1st Session, Senate.
7. 'Exec. Doc. 35,' 49th Congress, 1st Session, Senate.
8. 'Exec. Doc. 36,' 49th Congress, 1st Session, Senate.
9. 'Tests of Metals, Watertown Arsenal,' 1888.
10. 'Technology Quarterly,' vol. ix., Nos. 2 and 3, June and September 1896.

Of these Nos. 2, 4, 5, 6, 7, 8, and 9 were made at Watertown Arsenal; No. 3 contains a few tests where the columns were of practical sizes, together

with many where they were not; No. 10 contains a few tests of wrought-iron pipes used as columns.

In the tests made at Watertown Arsenal we have a long series on wrought-iron built up bridge columns.

Timber Columns.

1. 'Exec. Doc. 1,' 47th Congress, 1st Session, House.
2. Report of tests on full-size wooden mill columns, by G. Lanza, 1882.
3. 'Exec. Doc. 1,' 47th Congress, 2nd Session, Senate.
4. 'Journal Assoc. Engineering Societies,' Nov. 1889.
5. 'Technology Quarterly,' vol. viii., 1895.
6. Bauschinger, 'Mittheilungen aus dem Königl. Mech. Tech. Lab., Heft 9 and Heft 16.
7. 'Transactions Canadian Soc. Civil Engineers,' vol. ix., 1895.

The tests cited in Nos. 1, 2, 3, and 4 were made at Watertown Arsenal, and comprise a very extensive series of tests of full-size timber columns; those cited in No. 5 were made at the Massachusetts Institute of Technology, those in No. 6 by Professor Bauschinger at Munich, and those in No. 7 by Professor Bovey at McGill College, Montreal.

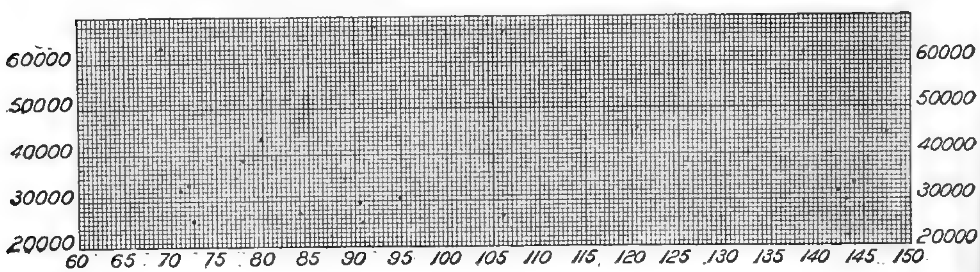
In order to represent to the eye the results of these tests, and therefore to enable us to discuss them, the following diagrams are presented:—

1. A diagram showing the results of the tests of cast-iron mill columns.
2. A series of four diagrams showing the results of the tests of wrought-iron bridge columns, and also empirical formulæ representing in each case the right-hand portion of the curve, which is concave upwards.
3. A series of four diagrams showing the results of the tests of timber columns cited in Nos. 1, 2, 3, and 5.

In 1 and 2 the abscissæ represent the ratio of length to least radius of gyration, and in 3 the ratio of length to least diameter, while the ordinates represent, in all the diagrams, the breaking loads per square inch of sectional area.

A study of these diagrams, and of the details of the tests which they represent, gives us the facts in regard to the strength of full-size columns, and shows that neither the experiments of Eaton Hodgkinson upon small samples nor the usual

FIG. 1.—Cast-iron Columns from Pacific Mills.



Abscissæ, length divided by radius of gyration of smallest section.
Ordinates, breaking strengths per square inch of smallest section.

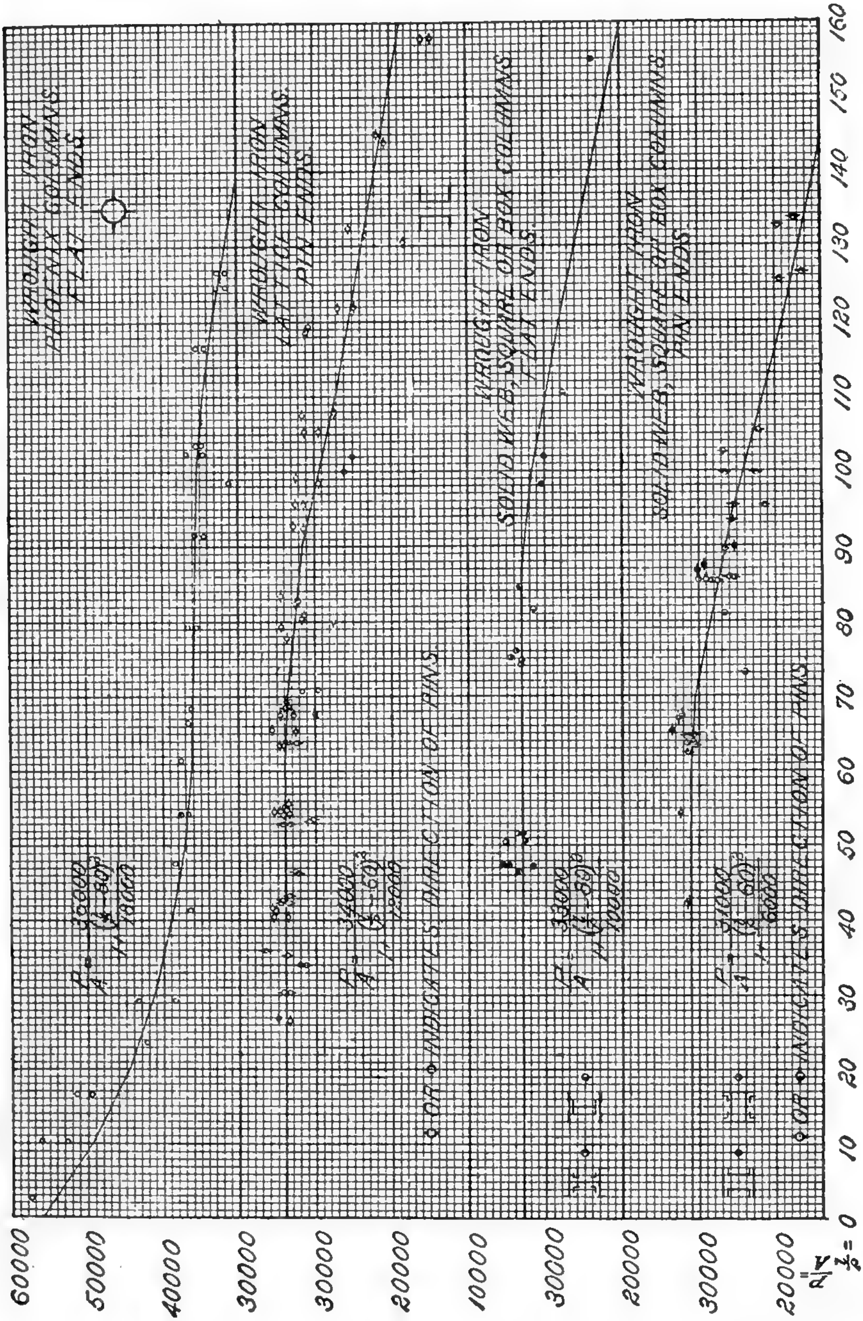
Euler or Gordon theories (so commonly quoted in the handbooks) are borne out by the facts.

A perusal of all the diagrams show that, whenever the load on a column is so applied that its resultant acts along the axis of the column, the breaking load per square inch of sectional area is practically constant up to a certain ratio of length to radius of gyration, which in wrought-iron bridge columns varies from sixty to eighty, and in a corresponding way to timber columns.

(The apparent exception occurring in the diagram for the Phœnix columns is clearly due to the effect of the friction of the platforms of the testing machine on the columns of very small ratio of length to radius of gyration.)

For higher values of the ratio of length to radius of gyration the breaking

FIG. 2.—Graphic Representations of Results of Tests of Wrought-iron Columns.



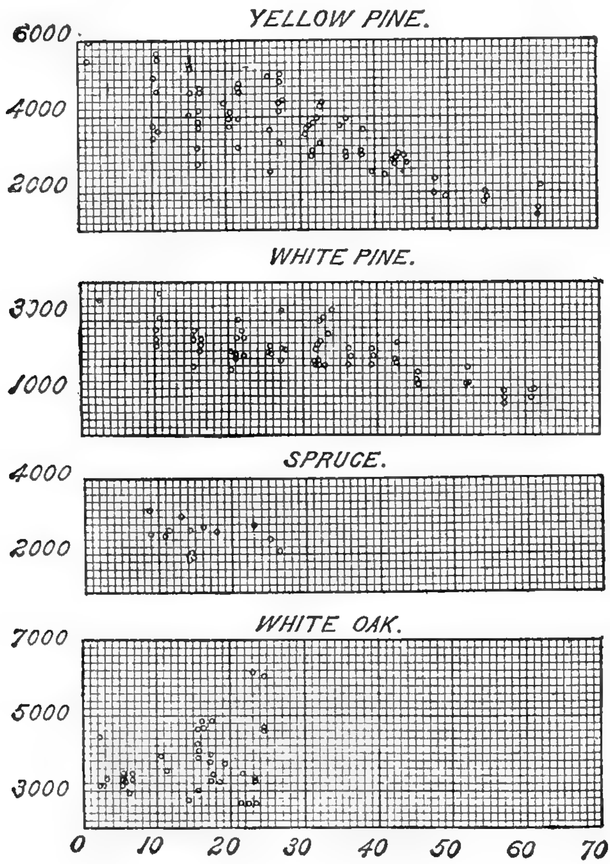
strength per square inch decreases, and the law of decrease can only be expressed empirically in each case.

When, on the other hand, the load on the column is eccentric, we should not fail to take this into account in our calculations, and should always compute the

greatest fibre stress by adding the direct stress per square inch to the greatest fibre stress arising from the bending moment due to the eccentricity of the load; and we should then so proportion the column that the total greatest fibre stress shall not exceed a certain allowable fibre stress, which last must be a sufficiently small fraction of the breaking strength per square inch corresponding to the ratio of length to radius of gyration of the column, as shown by the diagrams.

In the paper itself the results of the tests and the modes of computation, both for central and for eccentric loads, were treated more in detail, and then a discus-

FIG. 3.—Diagrams of Results of Tests of Timber Columns.



sion was given of the theories and formulæ commonly found in the handbooks which are, for the most part, based on the results of Hodgkinson's tests on small samples, and fuller attention was also called, in the paper, to the disagreement of these latter with the facts.

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3. *Results of Experiments on the Strength of White Pine, Red Pine, Hemlock, and Spruce. By* Professor H. T. Bovey, *M.Inst.C.E.*

This Paper contained 10 Tables giving the results of experiments on the transverse strength of 29 beams: of these, *nine* were of white pine, *eight* of red pine, *seven* of hemlock and *five* of spruce; while *nine* were kiln-dried, *four* were saturated and frozen, and *sixteen* were more or less air-dried.

The Paper also contained seventeen tables giving the results of experiments on the direct tensile and compressive strength and of the shearing strength of speci-

mens prepared from the beams tested transversely. The following inferences were drawn:—

(a) The tensile strength does not seem to be much affected by kiln-drying, but in the majority of cases it is diminished.

(b) Kiln-drying invariably and greatly increases the compressive strength.

(c) Kiln-drying invariably and greatly diminishes the shearing strength, and therefore increases the tendency of beams to fail by longitudinal shear.

(d) The transverse strength is increased by kiln-drying, in consequence of the increased strength given to the portion of the timber in compression.

(e) Kiln-drying increases the co-efficient of elasticity, and with kiln-dried specimens the changes of deflection and length are practically directly proportional to the changes of load, whether the specimen is being loaded or relieved of load.

(f) The last (viz. e) is also true of specimens in a normal state, *i.e.* specimens in which the moisture is in equilibrium with the moisture present in the atmosphere.

(g) Timber is extremely sensitive to variations in the hygrometric condition of the atmosphere.

(h) The development of shakes and the tendency to longitudinal shear are much less in specimens which have been air-dried than in those which have been kiln-dried.

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4. *A New Apparatus for Studying the Rate of Condensation of Steam on a Metal Surface at Different Temperatures and Pressures. By* H. L. Callendar, *M.A., F.R.S., Professor of Physics, and* J. T. Nicolson, *B.Sc., Professor of Mechanical Engineering, of McGill University, Montreal.*

[Ordered by the General Committee to be printed *in extenso*. See Reports, p. 418].

As the result of some experiments by electrical methods on the measurement of the temperature changes of the walls and steam in the cylinder of a working steam-engine, which were made at the McDonald Engineering Building of McGill University in the summer of 1895, the authors arrived at the conclusion that the well-known phenomena of cylinder condensation could be explained, and the amount of condensation in many cases predicted, from a knowledge of the indicator card, on the hypothesis that the rate of condensation of steam, though very great, was not infinite, but finite and measurable. An account of these experiments was communicated to the Institute of Civil Engineers in September 1896, and will, it is hoped, be published in the course of the ensuing year. In the meantime the authors have endeavoured to measure the rate of condensation of steam under different conditions by a new and entirely different method, with a view to verify the results of their previous work, and also to estimate the probable effect of wetness or superheating of the steam, and the influence, if any, of the film of water adhering to the walls of the cylinder.

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5. *Tests on the Triple-expansion Engine at Massachusetts Institute of Technology. By* Cecil H. Peabody, *Professor of Marine Engineering and Naval Architecture.*

The experimental engine is a horizontal three-crank triple-expansion engine, built by the E. P. Atlis Company of Milwaukee. The diameter of the high-pressure cylinder is 9 inches, that of the intermediate cylinder is 16, and that of the low-pressure cylinder is 24 inches. All these pistons have a stroke of 30 inches. The high-pressure and intermediate cylinders have Corliss valves of the ordinary type, moved by eccentrics with a small angular advance. The valves for the low-pressure cylinder are moved by two eccentrics, each working its own wrist plate; one of the eccentrics has a small angular advance, and

works the exhaust valves, which, as usual, have a small lap; the other eccentric has a large negative angular advance, and controls the admission valves, which are set with $\frac{3}{8}$-inch clearance. This separation of the admission and exhaust valve gear allows the cut-off to be prolonged to about $\frac{2}{3}$ stroke without changing the action of the exhaust valves.

A single powerful bail governor is given control of the cut-off valves for all three cylinders; but any set of valves may be disconnected from the governor, and then the cut-off by those valves may be raised by hand while the engine is running. It is the practice in the laboratory to allow the governor to retain control of the high-pressure admission valves only, those for the other cylinders being adjusted for each test by hand. This arrangement throws a very light duty on the governor, so that with the aid of a heavy fly-wheel it regulates the engine very closely, and successive indicator diagrams from the several cylinders are very nearly identical.

Intermediate receivers, each several times as large as the cylinders connected to it, are placed between the high and intermediate and between the intermediate and low-pressure cylinders. In each receiver there is placed an efficient reheater, made of copper tubing.

The several cylinders are provided with steam jackets on the heads and the bands. A proper system of pipes and valves allows steam to be supplied to or excluded from any steam jacket or either receiver reheater. The condensed water from the jackets of any cylinder, or from either reheater, is collected in a closed receptacle and measured by displacement, five such receptacles being provided.

The steam-piping is arranged so that boiler steam may be supplied to any cylinder independently; and the exhaust pipes from the several cylinders are so connected that various combinations of compounding can be made. For example, steam may be exhausted from the middle cylinder into both receivers, and may then pass into both the small and the large cylinders, which then act as low-pressure cylinders. The exhaust steam in any case is finally condensed in a surface condenser, and is collected and weighed in two tanks on scales.

Tests on this engine are made as a part of the regular class work in the steam-engineering laboratory, all observations and calculations being made by the students. But the work is all under the careful supervision of competent instructors, who also calculate all the results to give a standard with which the students' calculations are compared. It is our experience that this method gives at once the best instruction to the students and very reliable results, which have been published from time to time for the information of engineers. The paper of which this is an abstract gives a *résumé* of all the tests that have thus far been made.

The standard time for an engine test is one hour, which has been found to be abundant, provided the engine has been running a sufficient time under constant condition when the test is begun. When steam is supplied to the jackets of the cylinders during the test fifteen or twenty minutes' preliminary running is enough, but when steam is not admitted to the cylinders one hour is required, it being the habit to start the engine when cold by first warming all the cylinders by aid of the steam jackets.

Tests have been made on the engine running as a triple-expansion engine, and also running compound, using sometimes the small cylinder and the large cylinder, and sometimes the intermediate and the large cylinders. The several combinations have been tested, both with and without steam in the jackets. The best results have been attained when the engine is run triple-expanding, with steam supplied to the jackets on the heads and the barrels of all three cylinders. With a boiler pressure of 150 pounds, and with cut-off at one-third stroke for the high-pressure cylinder, the engine develops 150 horse-power at 90 revolutions per minute, and uses 13·7 pounds of steam per horse-power per hour, or 233 B.T.U. per horse-power per minute.

When no steam is supplied to the jackets of any of the cylinders the engine runs 270 B.T.U. per horse-power per minute, so that the ratio of the heat consumption with and without steam in the jackets is

$$233 : 270 = 1 : 1{\cdot}16.$$

When steam is supplied to the jackets on the heads of the cylinders, but not to those on the barrels, the heat consumption is 262 B.T.U. per horse-power per minute, giving a ratio of

$$233 : 262 = 1 : 1{\cdot}12,$$

which shows an appreciable but not a large effect from using steam in the jackets on the heads of the cylinders.

It is to be remarked that this engine under its most favourable conditions shows a very good efficiency, *i.e.*, 0·183. This is 0·736 of the efficiency of Camot's cycle for the same range of temperatures, and is 0·813 of that of a non-conducting engine having the same range of pressure.

MONDAY, AUGUST 23.

The following Report and Papers were read:—

1. *Report on Small Screw Gauges.*—See Reports, p. 426.

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2. *Montreal Electric Tramway System.* *By* G. C. CUNNINGHAM.

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3. *The Present Tendencies of Electric Tramway Traction.* *By* J. G. W. ALDRIDGE, *A.M.Inst.C.E.*

Tramway work is at the present time, and has been for some years past, characterised by an increasing use of mechanical traction systems. The reasons for this are obvious and self-evident. It is, however, worth while to look into the considerations that, so far as electric traction is concerned, have caused one system or another to grow into favour, noting also the inherent qualities or attributes of each, which must have an effect on future developments.

The United Kingdom has practically 130 miles of electric tramway at work or under construction; of this length $103\frac{1}{2}$ miles are operated on the trolley or overhead wire system, $15\frac{3}{4}$ miles by means of a third rail conductor, 6 miles by means of storage batteries, and only 4 miles on the underground conduit system.

These proportions may be taken as fairly representative of other countries also, as far as can be ascertained.

They seem likely to be maintained or even increased in favour of the overhead wire system, unless radical improvements can be made in the direction of a cheaply built and maintained conduit method, or more durable and light accumulators for placing direct upon the car. Objections to the overhead trolley wire system are almost entirely æsthetic, but at the same time have such great weight and force that every incentive is offered to the genius of invention to make improvements in other directions.

The ordinary underground conduit with open slot is most expensive to instal and troublesome to maintain efficiently; it cannot be built for less than 10,000*l.* or 12,000*l.* per mile. Even its latest form (consisting practically of an underground trolley wire) must require an outlay of nearly double the cost of an overhead wire system.

Closed conduits with surface contacts usually operated by means of electromagnetic switching devices in boxes under the street level are complicated, and it is to be feared are unreliable. The great weight of lead required on each car for accumulator traction means practically that the live paying load can never reach 25 per cent. of the gross weight of loaded car; whilst the combinations of trolley wire and battery, attempted on systems like those of Hanover and Dresden, are obviously ill-designed, the dead weight of battery being carried throughout the entire journey, though it is only required for part thereof.

The overhead trolley wire system therefore appears likely to come into still greater use than has already been the case, if only on the ground of economy; but in view of its admitted defects, the author has worked out an alternative method which avoids the erection of trolley wires along the streets above the tracks.

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4. *On a New Method of Measuring Hysteresis in Iron. By* J. L. W. GILL, *B.A.Sc., of McGill University, Montreal.*

[Communicated by Professor CALLENDAR, M.A., F.R.S.]

When a specimen of iron is passed to and fro through a magnetic field without any motion of rotation, the direction of the field being reversed each time the specimen passes out of the field, the iron passes through a complete magnetic cycle for each cycle of motion, and a definite amount of energy is lost, due to hysteresis in the iron. Since energy is supplied only in the form of mechanical work upon the specimen, the hysteresis loss is, by the law of the conservation of energy, numerically equal to the resultant mechanical work expended.

The instrument described below is based upon the above principle, and its function is to measure the work so expended.

The magnetic field is obtained by the use of a solenoid wound on a brass tube. This solenoid is arranged vertically and has a vertical motion, the ends of the solenoid being fitted with collars, which slide on two rigid vertical rods. An arm is fastened rigidly to the solenoid, and extends out on one side. To this arm is fastened a cord, which passes over a grooved pulley vertically above. A balance-weight is attached to the other end of the cord. By rotating the grooved pulley the solenoid may be moved up and down, and will remain in any desired position. The specimen to be tested is placed in a stirrup, which is sufficiently small to pass through the solenoid, and is suspended by a helical spring, the point of suspension being vertically above the centre of the solenoid. Another helical spring extends from the bottom of the stirrup to a point vertically below. This serves to keep the stirrup steady. The stirrup is suspended so that when the solenoid is in its lowest position the specimen is out of the magnetic field, being above the solenoid. As the solenoid is moved up the stirrup and specimen pass through it, and when the solenoid is in its highest position the specimen is practically out of the field. If the solenoid be moved once up and down, the field being reversed when the specimen is out of it, the specimen passes through a complete magnetic cycle, provided the specimen has been once through the field and is initially in that particular cyclic state.

As the solenoid is moved up, the specimen is attracted down, the force of attraction increasing until it reaches a maximum when about one-half of the specimen is inside the solenoid. The attraction then decreases and becomes zero when the specimen is in the centre of the solenoid. Up to this point work is being done by the magnetic force. As the solenoid is moved up to its highest position the specimen is attracted upward, and work is done against the magnetic force; the attracting force becomes a maximum when the specimen is about one-half out of the solenoid on the lower side, and becomes zero when the solenoid is in its highest position. The maximum force in the second half of the motion is greater than the maximum force in the first half. The work done in the second half of the motion is also greater than that done in the first half, the difference being the work expended in taking the specimen through half a cycle. When the field is reversed and the solenoid moved down, the action is similar to that which takes place when the solenoid is moved up, and the resultant work done will be the same, provided the specimen is homogeneous.

The resultant work done on the specimen may be determined by observing the attracting force when the solenoid is in different positions, and then drawing a distance-force curve. The integral of this curve gives the resultant work done on the specimen. The force at different points can be determined by calibrating the springs which support the stirrup, and then observing the extension of these springs. The author has determined the hysteresis loss in different specimens at

different inductions by this method, the extension of the springs being observed with the aid of a microscope.

To make this method practical, a simple integrating apparatus is attached to the instrument above described, by which the work done is integrated automatically. A glass disc is connected rigidly to the pulley which moves the solenoid, so that when the pulley rotates, the glass disc rotates in its own plane, which is vertical, the axis of rotation passing through its centre. The motion of the glass disc is therefore proportional to the motion of the solenoid. An arm is fastened to the stirrup which supports the specimen, and extends up to the glass disc. This arm supports a graduated steel disc, which is free to rotate in its own plane about a vertical axis through its centre. This steel disc presses lightly on the glass disc, the point of contact being at the centre of the glass disc. When the solenoid is moved up, the specimen is attracted down, taking the stirrup with it. This causes the steel disc to recede from the centre of the glass disc. A motion of rotation is then communicated to it by the glass disc, the speed of rotation depending on its distance from the centre; since its distance from the centre at any instant is proportional to the attracting force, and the motion of the glass disc is proportional to the motion of the solenoid, the speed of rotation of the disc is proportional to the work being done at that instant. The total amount of rotation is therefore proportional to the total work done. Consequently all that is necessary to test a specimen with this instrument is to place the specimen in the stirrup, move the solenoid up and down to get the specimen in a cyclic state, then take it through a cycle, and observe the amount of rotation communicated to the steel disc. This is a direct measure of the work expended.

The constant of the instrument is determined by placing a known weight in the stirrup, and observing the amount of rotation communicated to the disc when the solenoid is moved through a known distance.

The specimen may be taken through a number of cycles and the readings allowed to accumulate. The average of a number of cycles is thus obtained.

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5. *A New Method of Investigating the Variation of the Magnetic Qualities of Iron with Temperature. By* F. H. Pitcher, *M.A.Sc., Demonstrator of Physics, McGill University, Montreal.*

[Communicated by Professor H. L. Callendar, M.A., F.R.S.]

Owing to the apparent lack of exact knowledge on the subject of the variation of hysteresis in iron with temperature, and as it is of some importance in the working of transformers, it was thought well to investigate the subject further.

At the same time it was intended to repeat the experiments of Hopkinson and others on magnetism at high temperatures, by a different method and with higher fields. For this purpose a new method, devised by Professor Callendar, was employed.

Description of the Method.

The specimen of iron in question was in the form of a wire, and was tested by the direct magnetometric method in the broad side-on position. The first intention was to insulate the specimen in a small and very thin platinum tube, heated by having a current passed through it. The temperature of the specimen was to be inferred from the resistance of the platinum tube over the length occupied by the iron wire specimen. The resistance was to be measured by the fall of potential between the terminals of very fine platinum wire leads, attached to the platinum tube at the ends of the above length.

In this way, if the tube were made considerably longer than the wire, the middle portion occupied by the wire would be very uniformly heated, and very exact values of the mean temperature could be obtained. The slack of the platinum tube when heated was arranged to be taken up by copper springs. To prevent oxidation of the iron wire specimen, and at the same time to promote a

steady temperature throughout the length of the platinum tube, the whole was inclosed in a vacuum tube. The vacuum was maintained by a five-fall Sprengel pump, which was kept running during the experiment and was assisted by a water-pump in the early stages of exhausting the tube.

With this method in view, a platinum tube was constructed from a strip of foil 20 cm. long, 2·95 cm. wide, and 0·00254 cm. thick. It was rolled around a mandrel 0·438 cm. diam., and after annealing kept its dimensions without necessitating binding wires. The fine platinum leads were attached by winding their ends once around the tube and twisting up tight. A specimen of iron wire was threaded through mica wads of the same diameter as the mandrel, and slipped into position inside the platinum tube. The ends of the platinum tube were bound with bare copper wire to ♯0 copper rods, and the whole carefully centred in a glass tube.

The tube was exhausted, and a preliminary test for uniformity of heating made before placing it in the solenoid. It was seen to be heated very uniformly up to 2 cm. from each end. The apparatus was then fixed in position in the solenoid, and the whole placed in position with respect to the magnetometer. It was found, however, that platinum tubes constructed in this manner from thin foil would not stand at high temperatures. Two others were tried, which, on account of not having thicker foil of sufficient length, had to be constructed out of foil of one-half the thickness—one being wound three times around the mandrel and the other five times. These shared the same fate as the first one, giving way in circular cracks running sometimes over one-half the width of the foil.

The initial extension of the copper springs was not more than 2 mm. in any case, and the ends of the tubes made as square as possible so as to equalise the tension. This method was therefore abandoned until drawn tubes of suitable thickness could be obtained. In the meantime the platinum tube was replaced by the iron wire specimen itself, and in this way observations were obtained, and, by making the specimen its own thermometer, very exact values of its temperature could be obtained.

By heating the specimen in this manner there would be a strong circular field due to the heating current. The curves plotted from the temperature and magnetometer readings would therefore have to be corrected for this circular magnetism. This was effected in the manner explained, which, however, limited the temperature to which the wire could be raised. A set of observations was taken with the specimen in air and another in a high vacuum. The true magnetic behaviour of the iron with temperature could then be obtained from these two sets.

Description of Apparatus.

The Solenoid.—The magnetising coil as made in the laboratory was wound on a brass tube about 70 cm. long and having an outside diameter of 2·23 cm. The tube was fairly straight, and previous to winding was filed up and polished in a lathe and then carefully lacquered.

Winding.—

Length of winding	. . . .	60·25 cm.
Depth ,,	(4 layers double silk covered ♯24 B. and S.)	0·245 ,,
Whole number of turns	. . . .	4079·0 ,,
Total resistance	. . . .	28·1 ,,

This winding was fed on by hand in a lathe and was very fairly uniform. Each layer was carefully paraffined before winding the next. The insulation resistance when finished, as tested on 100 volts, was over a megohm. The winding was backed up at the ends by square ebonite washers which were fixed to the tube by brass set screws.

The Water-circulation.—A water-circulation was arranged for dissipating the heat when large magnetising forces were used. A thin brass tube was chosen, so that if it were slipped into the solenoid tube the annular space between them would be about 2 mm. The smaller tube was centred by brass rings fitted at the ends to the annular space between the tubes. The joint was made tight by solder-

ing. The water-circulation was effected by two small brass tubes, about 0·75 cm. diameter, entering laterally through the solenoid tube beyond the ebonite end into the spaces between the tubes.

Combined Galvanometer and Magnetometer.—This instrument was simply a mirror galvanometer, mounted on levelling screws, and with two coils of copper wire fitted closely on each side of the needle. The instrument was made fairly dead beat by employing a large thin aluminium vane, just fitting the needle chamber, to carry the mirror and needle. The resistance of the coils was found to be 100·3 ohms at 18°·7 C. It was used for measuring currents and resistances by the fall of potential method. The direct effect of the solenoid was balanced in the usual way by a balancing coil.

The Mounting for the Iron Wire Specimen.—The iron wire specimen was 26·1 cm. long and 0·127 cm. diam. Its ends were fused to copper wires 10·5 cm. long and 0·40 cm. diam., an arrangement intended to conduce to a constant temperature throughout the length of the iron wire when the heating current was passed through the circuits. The ends of the copper wire were riveted and tin-soldered to two ♯ 0 B. & S. copper rods, which were brought out at both ends of the containing tube. The rods were at about 6 cm. from their inside ends, and copper springs, 3 strands ♯ 18 B. & S., wound oppositely, were introduced to take up the slack of the specimen and copper wires when heated. The springs fitted the inclosing glass tube fairly well, but better centring was obtained by brass washers soldered on the 6 cm. segments at about 5 cm. apart and turned up to fit the tube.

Two fine platinum wires, for potential leads, were attached at 15 cm. apart to the iron wire specimen. They were brought out in glass capillary tubes running through diametrically opposite holes in the washers and inside the springs to one end of the glass containing tube. The ends of the capillary tubes were allowed to protrude about 5 cm. beyond the containing tube, and were fused at both ends to the platinum wires.

The diameter of the platinum leads was 0·005 cm.; total length, 98·0 cm.; resistance, 8·06 ohms.

The glass containing tube was made tight at the ends in the following manner. At the end where the capillary tubes were brought out a large brass cup, 2 cm. deep and 2 cm. internal diameter, drilled through the bottom to fit the rod and capillary tubes, was threaded over into position and soldered to the rod. This tube just fitted the inner solenoid tube, and had an internal diameter of about 1·27 cm. It was slipped over the apparatus till its end reached the bottom of the cup. The cup was then filled with melted fusible alloy, and to make tightness doubly sure a mixture of beeswax and resin was run around all the joints. The other end of the glass tube was drawn down so as nearly to fit the copper rod, and a similar but, on account of having to go through the solenoid tube, smaller cup soldered to the rod, after putting a small initial extension of about 2 mm. in the springs.

The seal was made in the same way as before. The connection to the pump was made by means of a small copper tube entering through the bottom of the brass cup and sweated in with solder. It was bent up at a right angle to facilitate a mercury immersion joint. The length of glass tube between the cups was 61 cm., which was about 2 cm. longer than the inner brass tube of the solenoid.

When the apparatus was in place so that the specimen was symmetrical with respect to the solenoid, the small brass cup was just at the end of the inner solenoid tube. Three brass set screws, ranged symmetrically, were tapped through this end of the solenoid tube and screwed down hard on the cup. At the other end of the solenoid tube a brass binding screw was soldered. This, with a similar screw on the adjacent end of the copper rod, formed the heating current terminals. By making the heating current return around itself in this way, its direct effect on the magnetometer was minimised.

A compressed fibre block was screwed to the copper rod near the ends of the capillary tubes, and vertical holes drilled side by side in it, to form mercury cups for the platinum leads. Twin wire leads of approximately equal resistances were brought from the terminals of the standard resistances in the magnetising and

heating current circuits, together with a similar pair from the mercury cups at the ends of the platinum potential leads, to three pairs of mercury cups on the table near the telescope and scale. The readings for magnetising current, heating current, and E.M.F. over the specimen could be very conveniently and quickly obtained by dipping the ends of the galvanometer leads into each pair of cups in turn.

TUESDAY, AUGUST 24.

The following Papers were read:—

1. *Some Tests on the Variation of the Constants of Electricity Supply Meters with Temperature and with Currents. By* G. W. D. Ricks.

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2. *Roller Bearings. By* W. B. Marshall.

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3. *Analysis of Speed Trials of Ships. By* W. G. Walker, *M.Inst.M.E., A.M.Inst.C.E.*

Only about 50 per cent. of the indicated horse-power of the engines of a ship is absorbed in actually propelling the vessel, the other half being wasted in the friction of the machinery and the resistance and slip of the propeller. The indicated horse-power developed by the engines may be divided into the following five constituent parts:—

1. The power necessary to overcome the friction of the unloaded engines.
2. The power to overcome the friction due to the working load.
3. The power to overcome the skin friction of the propeller blades.
4. The power expended in the slip of the propeller.
5. The power necessary for the propulsion of the vessel.

The power necessary for the propulsion of the vessel can be subdivided into two parts.

1. The power required to overcome the skin friction of the ship.
2. The power due to the formation of waves.

The author had carried out a series of progressive speed trials on a river steamer 60 feet long. The steam pressure necessary to overcome the friction of the unloaded engine was equal to about 9 lb. per square inch. The friction due to working load was taken at $7\frac{1}{2}$ per cent. of the net power, the net power being obtained by subtracting friction of unloaded engine from the total power, the blade friction was taken at ·45 lb. per square foot of blade surface when moving in its helical path at a velocity of 10 feet per second, and for other speeds in the ratio of the square of those speeds to the square of 10. If the first three quantities are subtracted from the indicated horse-power there remains a quantity the sum of the power spent in the action and reaction of the propeller; from this remainder was subtracted the slip, and the final remainder was the power required to propel the vessel. This final power divided by the net power is a measure of the efficiency of the screw. Taking the results for speed of vessels at seven miles per hour, which was the working speed we have, initial friction equals 15 per cent. of the I.H.P., friction of load 6 per cent. of I.H.P., friction of screw 3·4 per cent. of I.H.P., slip of screw 25 per cent. of I.H.P., propulsion 50 per cent. of I.H.P., skin friction of vessel 27 per cent. of I.H.P., power lost in wave formation 23 per cent. of I.H.P. The general shape of the efficiency curve of the propeller is almost the same for all screws; being zero at zero speed, it rises to a maximum at a certain speed, and afterwards falls off with further increase of speed. The object is to design a propeller so that its maximum efficiency occurs at the working speed of the vessel.

Having carried out a progressive series of experiments on a steamer, it becomes an easy matter to modify the design of the existing propeller so that its maximum efficiency shall occur at the working speed of the ship. The maximum efficiency of a screw-propeller is about 70 per cent.; in the experiment carried out, it was 70 per cent. at 4 miles per hour, and 59 at 7 miles per hour.

4. *A Modern Power Gas Plant Working in a Textile Factory.* *By* H. Allen.

5. *Effect of Temperature in Varying the Resistance to Impact, the Hardness, and the Tensile Strength of Metals.* *By* A. Macphail.

Section H.—ANTHROPOLOGY.

President of the Section—Sir William Turner, M.B., LL.D., D.C.L., F.R.S., F.R.S.E.

The President delivered the following Address on Friday, August 20:—

Some Distinctive Characters of Human Structure.

When the British Association for the Advancement of Science held its first Canadian meeting at Montreal in 1884, the subject of Anthropology, or the Science of Man, attained on that occasion for the first time the rank of an independent Section.

It was presided over by the accomplished writer and learned anthropologist Dr. E. B. Tylor, who selected as the subject-matter of his opening address several prominent questions in Anthropology, with special reference to their American aspects. For example, the question of the presence of a stone age in America; whether the aborigines are the descendants and representatives of man of the post-glacial period; the question of the Asiatic origin of the American Indians, and the arguments derived from anatomical structure, language, and social framework, bearing upon this theory. The traces of Asiatic influence in the picture writings of the Aztecs, correspondences in the calendar cycles of Mexico and Central America with those of Eastern Asia, and the common use of certain games of chance were also referred to.

It is not my intention, even had I possessed the requisite knowledge, to enlarge on the topics so ably discussed by my eminent predecessor. As my own studies have been more especially directed to the physical side of Anthropology, rather than to its archæological, historical, philological, moral and social departments, I naturally prefer to call your attention to those aspects of the subject which have from time to time come within the range of my personal cognizance. I have selected as the subject of my address 'Some Distinctive Characters of Human Structure.'

When we look at man and contrast his form and appearance with other vertebrate creatures, the first thing probably to strike us is his capability of assuming an attitude, which we distinguish by the distinctive term, the erect attitude. In this position the head is balanced on the summit of the spine, the lower limbs are elongated into two columns of support for standing on two feet, or for walking, so that man's body is perpendicular to the surface on which he stands or moves, and his mode of progression is bipedal. As a consequence of this, two of his limbs, the arms, are liberated from locomotor functions; they acquire great freedom and range of movement at the shoulder-joint, as well as considerable movement at the elbow and between the two bones of the forearm; the hands also are modified to serve as organs of prehension, which minister to the purposes of his higher intelligence. The erect position constitutes a striking contrast to the attitude

assumed by fish, amphibia, and reptiles when at rest or moving, in which vertebrates the body is horizontal and more or less parallel to the surface on which they move. Birds, although far removed from the erect attitude, yet show a closer approximation to it than the lower vertebrates or even the quadrupedal mammals. But of all vertebrates, those which most nearly approximate to man in the position assumed by the body when standing and walking are the higher apes.

The various adaptations of structure in the trunk, limbs, head, and brain which conduce to give man this characteristic attitude are essential parts of his bodily organisation, and constitute the structural test which one employs in answering the question whether a particular organism is or is not human.

These adaptations of parts are not mere random arrangements, made at haphazard and without a common purpose; but are correlated and harmonised so as to produce a being capable of taking a distinctive position in the universe, superior to that which any other organism can possibly assume. If we could imagine a fish, a reptile, or a quadruped to be provided with as highly developed a brain as man possesses, the horizontal attitude of these animals would effectually impede its full and proper use, so that it would be of but little advantage to them. It is essential, therefore, for the discharge of the higher faculties of man, that the human brain should be conjoined with the erect attitude of the body. The passage of a vertebrate organism from the horizontal position, say of a fish, in which the back, with its contained spinal column, is uppermost, and the head is in front, to the vertical or erect position of a man, in which the back, with its contained spinal column, is behind, and the head is uppermost, may be taken as expressing the full range and limit of evolution, so far as the attitude is concerned, of which such an organism is capable. Any further revolution of the body, as in the backward direction, would throw the back downwards, the head backwards, and would constitute a degradation. It would not be an advance in the adaptation of structure to the duties to be discharged, but rather an approach to the relation of parts existing so generally in invertebrate organisms.

At an early period in the evolution of the human mind and intelligence an anthropomorphic conception of the Deity arose, to whom were ascribed the possession of the bodily form and attitude of man, and even human affections and passions. This idea took so firm possession of the imagination that, in the course of time, it obtained objective expression in the statues of ancient Greece and Rome and in the masterpieces of Christian art. In one of the most ancient of all books, in which is embodied the conception entertained by the Jewish writers of the Genesis of the world, and of all creatures that have life, we read that 'God created man in his own image, in the image of God created he him, male and female created he them.' By the association, therefore, of the human form with the idea of Deity, there was naturally present in the minds of these writers, although not expressed in precise anatomical language, a full recognition of the dignity of the human body, of its superiority to that of all other creatures, and that the human form was the crown and glory of all organic nature.

This conception of the dignity of man in nature is not confined to those writings which we are accustomed to call sacred. The immortal Greek philosopher and naturalist, Aristotle, in his treatise 'On the Parts of Animals,' composed at least three hundred years B.C., refers more than once to the erect attitude of man, and associates it with his 'God-like nature and God-like essence.' In the second century of our present era lived another Greek author, Claudius Galen, whose writings exercised for many centuries a dominating influence in medicine and anatomy, comparable to that wielded by Aristotle in philosophy. Although Galen, as has been shown by Vesalius and other subsequent anatomists, was often incorrect in his descriptions of the internal parts of the human body, doubtless because his opportunities of dissection were so scanty, he had attained a correct conception of the perfection of its external form, and he thoroughly understood that in its construction it was admirably fitted for the sentient and intelligent principle which animated it, and of which it was merely the organ. In his treatise on the use of the various parts of the body he associates the hand with the exercise of the gift

of reason in man, and he speaks of it as an instrument applicable to every art and occasion, as well of peace as of war. It is, he says, the best constructed of all prehensile organs, and he gives a careful description of how both the hand as a whole and the individual digits, more especially the thumb, are brought into use in the act of grasping.[1] Galen does not indeed enter into the minute anatomical details which have been emphasised by more recent writers on the subject, but by none of these has the use of the hand and its association with man's higher intelligence been more clearly and more eloquently expressed than by the Greek physician and philosopher seventeen centuries ago.

By the publication in 1859 of Charles Darwin's ever-memorable treatise 'On the Origin of Species,' an enormous impulse was given to the study of the anatomy of man in comparison with the lower animals, more especially with the apes. By many anatomists the study was pursued with the view of pointing out the resemblances in structure between men and apes; by a more limited number to show wherein they did not correspond. I well remember a course of lectures on the comparative characters of man delivered thirty-five years ago by my old master, Professor John Goodsir, in which, when speaking of the hand of man and apes, he dwelt upon sundry features of difference between them.[2] The human hand, he said, is the only one which possesses a thumb capable of a free and complete movement of opposition. It may be hollowed into a cup and it can grasp a sphere. It is an instrument of manipulation co-extensive with human activity. The ape's hand again is an imperfect hand, with a short and feeble thumb, and with other clearly defined points of difference and inferiority to that of man. It can embrace a cylinder, as the branch of a tree, and is principally subservient to the arboreal habits of the animal. Its fingers grasp the cylinder in a series of spirals.

Here then is an important difference in the manipulative arrangements of the two hands, the advantage being with the hand of man, in regard to the greater variety of movement and adaptability, to co-ordinate it with his reasoning faculties. As showing the acuteness of perception of Galen and his complete recognition of a fundamental feature of the human hand, he also dwells on the hand being able to form a circle around a sphere, so as to grasp it on every side, and to touch it with every part of itself, whilst it can also securely hold objects that possess plane or concave surfaces. So impressed was the old Greek writer with the fitness of the hand to discharge the duties imposed on it by the higher intelligence of man that, pagan though he was, he regarded its construction as evidence of design in nature, and as a sincere hymn to the praise and honour of the Deity.

It is not my intention to dwell upon the multitudinous details of those features of structure which distinguish man from other vertebrates, for these have been considered and described by numerous writers. The leading structural differentiæ constitute the merest commonplaces of the human anatomist, and are already sufficiently imprinted on the popular mind. But it may not be out of place to refer to certain aspects of the subject which are not so generally known, and the significance of which has been brought into greater prominence by recent researches.

If we compare the new-born infant with the young of vertebrates generally, we find a striking difference in its capability of immediately assuming the characteristic attitude of the species. A fish takes its natural posture and moves freely in its element as soon as it is hatched. A chicken can stand and walk when it is liberated from the egg, though, from its wings not being developed, it is not at once able to fly. A lamb or calf can assume the quadrupedal position a few minutes after its birth. But, as we all know, the infant is the most helpless of all young vertebrates, and is months before it can stand on two feet and move freely on them. During the period of transition,

[1] See passages translated in Dr. Kidd's *Bridgewater Treatise*, 1833, and Dr. J. Finlayson's *Essay on Galen*, Glasgow, 1895.

[2] 'On the Dignity of the Human Body,' in *Anatomical Memoirs*, by John Goodsir, vol. i. p. 238, Edinburgh, 1868.

from the stage of absolute dependence on others to the acquisition of the power of bipedal progression, important modifications in the structural arrangements both of the spine and lower limbs have to take place. At the time of birth the infant's spinal column exhibits only two curves; one, corresponding to the true vertebræ, extends from the upper end of the neck to the lowest lumbar vertebra, and the concavity of its curve is directed forwards; the other and shorter corresponds to the sacro-coccygeal region and also has its concavity directed forwards. In the number and character of the curves, the new-born infant differs materially from the adult man, in whose spine, instead of one continuous curve from the neck to the sacrum, there are alternating curves, one convex forwards in the region of the neck, succeeded by one concave forwards in the region of the chest vertebræ, which again is succeeded by a marked convexity forwards in the vertebræ of the loins. The sacro-coccygeal region continues to retain the forward concavity of the new-born child. The formation and preservation of this alternating series of curves is associated with the assumption of the erect attitude, and the development of the lumbar convexity is correlated with the straightening of the lower limbs when the child begins to walk.[1]

When the child is born, the curvature of its spine in the dorso-lumbar region approximates to that of an ordinary quadruped in which there is no lumbar convexity, so that the spine in that region presents one continuous curve concave forwards. For some time after its birth the infant retains the quadrupedal character of the spinal curve in the dorso-lumbar region, and, as it acquires nervous and muscular power and capability of independent movement, its mode of progression in the early months by creeping on hands and knees approximates to that of the quadruped. It is only after it has attained the age of from a year to sixteen months that it can erect its trunk, completely extend the hip and knee joints, and draw the leg into line with the thigh, so as to form a column of support, which enables it to stand or move about on two feet. Hence there is this great difference between the young of a quadruped and that of a man, that whilst the former is born with the dorso-lumbar curve proper to its attitude, and which it retains throughout life, the child does not possess, either when born, or for some months after its birth, the characteristic spinal curves of the man. These curves are therefore secondary in their production; they are acquired after birth, and are not imprinted on the human spine from the beginning, though the capability of acquiring them at the proper time is a fundamental attribute of the human organism.[2]

It has sometimes been assumed that the acquisition of the erect attitude by the young child is due to the fostering care of the mother or nurse; that it is a matter of training, encouragement and education, without which the child would not raise itself upon its feet. I cannot, however, agree with this opinion. If one could conceive an infant so circumstanced that, though duly provided with food fitted for its nutrition and growth, it should never receive any aid or instruction in its mode of progression, there can, I think, be little doubt that when it had gained sufficient strength it would of itself acquire the erect attitude. The greater growth in length of the lower limbs, as compared with the upper, would render it inconvenient to retain the creeping or the quadrupedal position.

We cannot lose sight of the important influence which, altogether independent of education, is exercised by parents on their offspring. The transmission of hereditary qualities, through the germ from which each individual organism is derived, is one of the fundamental and most striking properties of the germ plasm. Characters and peculiarities which appertain not only to the family of which the individual is a member, but also to the species to which he belongs, are conveyed through it from one generation to another. Hence, as the capability of assuming the erect attitude and of thus standing and moving on two feet have been attri-

[1] Professor Cleland, in *Reports of British Association*, 1863, p. 112.

[2] In his work on the *Origin and Progress of Language* (vol. i. p. 173, Edinburgh, 1773), Lord Monboddo held that the erect position in man is an acquired habit, and, like speech, is acquired with difficulty and as the result of training.

butes of the human form from its beginning, there can be little doubt that this power is potential in the human organism at the time of birth, and only requires a further development of the nervous and muscular systems to become a reality, without the aid of any special training.

The spinal column in the region of the true vertebræ consists of numerous bones jointed together, and with discs of soft fibro-cartilage interposed between and connecting the bodies of adjoining vertebræ with each other. It is to their presence that the spinal column owes its flexibility and elasticity. These discs are larger and thicker in the region of the loins, where the lumbar convexity is situated, than in other parts of the column, and there can be no doubt that the acquisition of this convexity is intimately associated with the presence of these discs.

It is a matter for observation and consideration to what extent the bodies of the vertebræ contribute to the production of this curve. A few years ago Professor Cunningham, of Dublin,[1] and I[2] undertook much about the same time researches into the form and dimensions of the bodies of these bones. Our observations were made independently of each other and on two different series of skeletons, and as we arrived at practically the same conclusions, we may, I think, infer that, in their main features at least, these conclusions are correct.

The method followed in the investigation was to measure the diameter from above downwards of the body of each of the five lumbar vertebræ, both in front and behind. If the upper and lower surfaces of the bodies of the vertebræ were parallel to each other, it is obvious that, so far as they are concerned, the column formed by them would be straight, as is the case in a column built of hewn stones possessing similar parallel surfaces. But if the surfaces are not parallel the body of the vertebra is wedge-shaped; should the front of the collective series of bones have a greater vertical diameter than the back, it is equally obvious that the column would not be straight, but curved, and with the convexity forwards. From the examination of a considerable number of spinal columns of Europeans, we found that, although the vertical diameter of the bodies of the two highest vertebræ was greater behind than in front, in the two lowest the anterior vertical diameter so greatly preponderated over the posterior that the anterior vertical diameter of the bodies of the entire series of lumbar vertebræ in each spine was collectively greater than the corresponding diameter of the posterior surface. In twelve European skeletons I observed that the mean difference was between 5 and 6 mm. in favour of the anterior surface. If we are to regard the collective vertical diameter anteriorly of the five bones as equal to 100, the same diameter posteriorly is only equal to 96, which may be regarded as the lumbar index in Europeans. Dr. Cunningham obtained a similar index from the examination of a much larger number of European skeletons, and he further showed that in women the lumbar convexity forwards is more pronounced than in men. It follows therefore, from these observations, that when the broad end of the wedge-shaped bodies is in front the bones themselves would by their form give a forward convexity to the spine in the lumbar region. But a similar wedge-shaped form is also possessed by the lower intervertebral discs in this region, and especially by that interposed between the last lumbar vertebra and the sacrum. Hence it follows that both vertebral bodies and intervertebral discs contribute in the white races to the production of the lumbar convexity.

When we pass to the examination of the corresponding region in the spines of those races of men that we are accustomed to call lower races, we find a remarkable and important difference. Let us take as a characteristic example of a lower race the aborigines of Australia. In their skeletons our observations have proved, that the vertical diameter of the bodies of the five lumbar vertebræ was collectively deeper behind than in front. In my series of skeletons the mean difference was between 6 and 7 mm. in favour of the posterior surface, so that they possessed the opposite condition to that which prevails in Europeans. Hence if the spine had

[1] 'The Lumbar Curve in Man and the Apes,' Cunningham, *Memoirs of the Royal Irish Academy*, Dublin, 1886.

[2] 'Report on Human Skeletons,' *Challenger Reports*, Part XLVII., 1886.

been constructed of vertebræ only, instead of a lumbar convexity, the column would have possessed a forward concavity in that region. For this character, as shown in the skeleton only, I have suggested the descriptive term 'Koilorachic.'

We know, however, that elastic discs are intercalated between the bodies of the osseous vertebræ in the black races as well as in Europeans. It is necessary, therefore, to examine their spinal columns, when the intervertebral discs are in position, in order to obtain a proper conception of the character of the curve in the living man.

A few years ago Professor Cunningham had the opportunity of studying the spinal column of an aboriginal Australian,[1] in which the intervertebral discs had been preserved in their proper position, in relation to the bones, without losing their flexibility, or their natural shape and thickness. He found that, whilst the bodies of the lumbar vertebræ were longer than in Europeans, the proportion of intervertebral disc to vertebral body was distinctly less, so that the disc appeared to be reduced in depth, in relation to the greater vertical diameter of the vertebral body. Notwithstanding this difference, as compared with the white man, the Australian spine had a marked lumbar convexity which showed no material difference from that seen in Europeans. As the lumbar curve was not due to the wedge-shaped form of the bodies of the vertebræ, it was therefore produced solely by the strong wedge-shape of the intervertebral discs, and was not, as in Europeans, a product of a combination of both these factors. The spinal column, when complete, is not therefore koilorachic in the lumbar region.

The greater vertical diameter of the bodies of the lumbar vertebræ behind than in front, as compared with Europeans, is not limited to the Australians, but is participated in by other black races, as the now extinct Tasmanians, the Bushmen, Andaman Islanders, and Negroes, which, if tested solely by the measurements of the skeleton, would also be koilorachic. But in these races intervertebral discs are also present, and there can be no doubt that through the compensating influence of the wedge-shaped discs, with their deeper ends in front, the lumbar curve is in them also convex forwards. It is clear, therefore, that in the black races the intervertebral discs play relatively a more important part in the production of the lumbar curve than in Europeans.

One of the requirements of civilisation is the wearing of clothes, and fashion frequently prescribes that they should be tight-fitting and calculated to restrict motion in and about the spinal column. In savage races, on the other hand, clothing is often reduced to a minimum, and when worn is so loose and easy as in no way to hamper the movements of the body. The spinal column retains therefore in them much more flexibility, and permits the greater measure of freedom in the movements of the trunk, which is found in savage man, and has often been referred to by travellers.

It used to be considered that the possession of a lumbar convexity in the spinal column was the exclusive privilege of man, and was shared in by no other vertebrate. There can be no doubt that it attains a marked development in the human spine, and as such is associated with the erect posture. But the observations of Cunningham on the spinal column of apes, more especially the anthropoid group, made in fresh specimens, in which the intervertebral discs were in place, have proved that in the Chimpanzee the lumbar convexity is probably as strongly pronounced as in the adult man. In a Chimpanzee, two years old, the development is more advanced that in a child of the same age. The lumbar convexity is established at an earlier age than in the child, for it would seem as if the Chimpanzee attained its maturity at a younger period of life than the human being. In the Orang the lumbar curve is more feeble than in Man and the Chimpanzee, and in the specimen described by Cunningham resembled that of a boy six years old. In a fresh specimen of the Gibbon, examined by the same anatomist, the lumbar curve was intermediate between the Chimpanzee and the Orang.

In 1888, I purchased the bones of an adult male Gorilla, in which the vertebræ

[1] *Proc. Roy. Soc. London*, January 24, 1889, vol. xlv.; also see *Journal of Anatomy and Physiology*, vol. xxiv. 1890.

were in position and connected together by the dried intervertebral discs. This condition is of course not so satisfactory, for the study of the spinal curves, as if the specimen had been fresh, and with the discs retaining their natural flexibility and elasticity. But it was quite obvious that the spine possessed an alternating series of convex-concave curves from above downwards. The cervical and lumbar convexities, more especially the latter, did not project so far forwards as in man, and the dorsal concavity was not so deep. The most projecting part of the lumbar convexity was at the junction of the bodies of the third and fourth lumbar vertebræ and their intermediate disc. A vertical line drawn downwards from the most prominent part of this convexity fell in front of the coccyx. When prolonged upwards it passed in front of the bodies of the dorsal vertebræ, and intersected the body of the sixth cervical vertebra, so that the bodies of the vertebræ, higher than the sixth, were directed obliquely from below upwards and forwards in front of the vertical line.

The dried state of the discs did not enable one to determine precisely the proportion in which they entered into the formation of the length of the column, but the vertical diameter of the interlumbar and lumbo-sacral discs was obviously not as great as in the human spine. On the other hand, the vertical diameter of the bodies of the lumbar vertebræ was greater than in man, so that the length of the lumbar spine, and possibly its degree of convexity, were due more to the bodies of the vertebræ than to the elastic discs interposed between them. The Gorilla corresponds with the Chimpanzee in having longer vertebral bodies and shorter intervertebral discs than in man.

Without going into the question whether a lumbar convexity exists in the tailed monkeys, the determination of which with precision is a matter of some difficulty, it must be obvious that the presence of this convexity can no longer be regarded as the exclusive prerogative of man. It undoubtedly forms an important factor in the study of the erect attitude; but in order that man should acquire and be able to retain his distinctive posture, something more is necessary than the possession of a spinal column with a curve in the lumbar region convex forwards.

Our attention should now be directed to the lower limbs, more especially to the two segments of the shaft, which we call thigh and leg.

If we look at a quadruped we see that the thigh is bent on the trunk at the hip joint, and that the leg is bent on the thigh at the knee joint; whilst the foot forms more or less of an angle with the leg, and the animal walks either on the soles of its feet or on its toes. In the Anthropoid apes there is also distinct flexure both of the hip and knee joints, so that the leg and thigh are set at an angle to each other, and the foot is modified, through a special development of the great toe, into an organ of prehension as well as of support. When we turn to the human body we find that in standing erect the leg and thigh are not set at an angle to each other, but that the leg is in line with and immediately below the thigh, that both hip and knee joints are fully extended, so that the axis of the shaft of the lower limb is practically continuous with the axis of the spine. The foot is set at right angles to the leg, and the sole is in relation to the ground. The vertical axis of the shaft of the lower limb, the extended condition of the hip and knee joints, and the rectangular position of the foot to the leg are therefore fundamental to the attainment of the erect attitude of man.

In narratives of travel by those who have studied the Penguins in their native habitats, you may read that these birds may be seen standing on the rocks on the coasts which they frequent, in rows, like regiments of soldiers, and the idea has become implanted in the minds of many that they can stand erect. Even so accomplished a writer and acute a critic as the late Mr. G. H. Lewes thought that the Penguins had the vertical attitude when standing, and that some mammals, as the Jerboa and Kangaroo, very closely approached to it. The attitude of man was, he considered, merely a question of degree, and did not express a cardinal distinction.[1]

In arriving at this conclusion, however, only the external appearance of the birds and mammals referred to by him can have been looked at. If the skin and

[1] Aristotle, *A Chapter from the History of Science*, p. 309, London, 1864.

flesh be removed, and the arrangement of the constituent parts of the skeleton be studied, it will be seen that the axis of the spine in them, instead of being vertical, is oblique, and that there is no proper lumbar convexity; that the hip and knee joints, so far from being extended, are bent; that the thigh is not in the axis of the spine, and that the leg, instead of being in a vertical line with the thigh, is set at an acute angle to it. The so-called vertical attitude therefore in these animals is altogether deceptive. It does not approximate to, and can in no sense be looked upon as equivalent to, the erect attitude in man.

We may now consider what agents come into operation in changing the curve of the spine from the concavity forwards, found in the new-born infant, to the alternating series of curves so characteristic of the adult. The production of the lumbar convexity is, without doubt, due to structures associated with the spine, the pelvis and the lower limbs, whilst the cervical convexity is due to structures acting on the spine and the head.

There can, I think, be little doubt that muscular action plays a large part in the production of the cervical and lumbar convexities. The study of the muscles, associated with and connected to the spinal column, shows that large symmetrically arranged muscles, many of which are attached to the neural arches and transverse processes of the vertebræ, extend longitudinally along the back of the spine, and some of them reach the head. On the other hand, those muscles which lie in front of the spine, and are attached to the vertebræ, are few in number, and are practically limited to the cervical and lumbar regions, in which the spine acquires a convexity forwards.

It has already been pointed out that the formation of the lumbar convexity is correlated with the power of extending the hip joints and straightening the lower limbs. When these joints are in the position of extension, an important pair of muscles called the 'psoæ,' which reach from the small trochanter of the femur to the bodies and transverse processes of the lumbar vertebræ, are in a state of tension. In the act of extending the hip joints so as to raise the body to the erect position, the opposite ends of these muscles are drawn asunder, and the muscles are stretched and elongated, so that they necessarily exercise traction upon the lumbar spine. Owing to its flexibility and elasticity, a forward convexity is in course of time produced in it in this region. By repeated efforts the convexity becomes fixed and assumes its specific character.

Along with the changes in the spinal column, a modification also takes place in the inclination of the pelvis during the extension of the hip joints and the straightening of the lower limbs. The muscle called 'iliacus' is conjoined with the psoas at its attachment to the small trochanter, but instead of being connected to the spinal column by its upper end, it is attached to the anterior surface of the ilium. It exercises traction therefore on that bone, draws it forwards and increases the obliquity of the pelvic brim. This in its turn will react on the lumbar spine and assist in fixing its convexity.

By some anatomists great importance has been given to the 'ilio-femoral band,' situated in the anterior part of the capsular ligament of the hip joint, as causing the inclination of the pelvis, and in promoting the lumbar curve. This band is attached by its opposite ends to the femur and the ilium. As the hip joint is being extended, the ends are drawn further apart, the band is made tense, and the ilium might in consequence be drawn upon, so as to affect the inclination of the pelvis. As the ligament has no attachment to the spinal column, it cannot draw directly on it, but could only affect it indirectly through its iliac connections. It can therefore, I think, play only a subordinate part in the production of the lumbar curve.

Contemporaneous with the straightening of the lower limbs and the extension of the hip joints, the spinal column itself is elevated by muscles of the back, named 'erectores spinæ,' which, taking their fixed points below, draw upon the vertebræ and ribs and erect the spine. The lumbar convexity is the form of stable equilibrium which the flexible spinal column tends to take under the action of the muscular forces which pull upon it in front and behind. It is probably due to the fact that the average pull, per unit of length, of the psoæ muscles attached in

front is greater than the average pull, per unit of length, of the muscles attached behind in the same region.

The muscles which lie on the back of the neck and which are attached to the occipital part of the skull, when brought into action, will necessarily affect the position of the head. The new-born infant has no power to raise the head, which is bent forward, so that the chin is approximated to the chest. As it acquires strength the head becomes raised by the muscles of the back of the neck, and the flexible spine in the cervical region loses its primary curve, concave forwards, and gradually assumes the cervical convexity. The formation of this curve is, I believe, assisted by the anterior recti muscles, the lower ends of which are attached to the front of the vertebræ, whilst their upper ends are connected to the basi-occipital. In the elevation of the head the opposite ends of the muscles are drawn apart, which would exercise a forward traction upon the cervical vertebræ. The production of the cervical convexity precedes the formation of the lumbar curve, for an infant can raise its head, and take notice of surrounding objects, months before it can stand upon its feet.

We shall now look at the bones in the thigh and leg, which possess characters that are distinctively human, and which are associated with the erect posture. These characters can be more clearly recognised when the bones are contrasted with the corresponding bones of the large Anthropoid apes.

As compared with the ape, the shaft of the human thigh bone is not so broad in relation to its length; when standing erect the shaft is somewhat more oblique, it is more convex forwards and generally more finely modelled, and it has three almost equal surfaces, the anterior of which is convex. But, further, a strong ridge (linea aspera) extends vertically down its posterior surface; so that a section through the shaft is triangular, with the two anterior angles rounded and the posterior prominent. In the Gorilla, Chimpanzee, and Orang, the shaft is flattened from before backwards, and the linea aspera is represented by two faint lines, separated from each other by an intermediate narrow area. A section through the shaft approximates to an ellipse. In the Gibbon the femur is greatly elongated, and the shaft is smooth and cylindriform. The linea aspera is for the attachment of powerful muscles, which are more closely aggregated in man than in apes, so that the human thigh possesses more graceful contours.

In the human femur the shaft is separated from the neck by a strong anterior intertrochanteric ridge, to which is attached the ilio-femoral ligament of the hip joint, which, by its strength and tension, plays so important a part in keeping the joint extended when the body is erect. In the Anthropoid apes this ridge is faint in the Gorilla, and scarcely recognisable in the Orang, Gibbon, and Chimpanzee, and the ilio-femoral ligament in them is comparatively feeble. It may safely therefore be inferred that in apes, with their semi-erect, crouching attitude, the ilio-femoral band is not subjected to, or capable of sustaining, the same strain as in man.

The head of the thigh bone is also distinctive. In the apes the surface covered by cartilage is approximately a sphere, and is considerably more than a hemisphere. It is sharply differentiated from the neck by a definite boundary, and it has a mushroom-like shape. In man the major part of the head is also approximately a sphere; but, in addition, there is an extension outwards of the articular area on the anterior surface and upper border of the neck of the bone. The form of this extended area differs from the spherical shape of the head in general. The curvature of a normal section of its surface has a much larger radius than the curvature of a normal section of the head, near the attachment of the ligamentum teres.

The amount of this extended area varies in different femora, but as a rule it is larger and more strongly marked in Europeans than in the femora of some savages which I have examined. When the joint is in the erect attitude, the area is in contact with the back of the iliac part of the ilio-femoral ligament. It provides a cartilaginous surface which, during extension of the joint, is not situated in the acetabulum, but, owing to the centre of gravity falling behind the axis of movement, is pressed against that ligament, and contributes materially to its tension. It is associated with the characteristic position of the human hip joint in

standing, and may be called appropriately the extensor area. When the femur is abducted it passes within the acetabulum. The head of the femur in man is not so sharply differentiated from the neck as in the Anthropoid apes, especially in the region of the extensor articular area.

Both man and apes possess at the lower end of the femur a trochlear or pulley-like surface in front for the patella, and two condyles for the tibia. In the apes the trochlea is shallow, and the concave curve from side to side is a segment of an approximate circle, with a large radius. In man the trochlea is much deeper, and the inner and outer parts of the curve deviate considerably from a circle, and are not symmetrical; the outer part is wider and extends higher on the front of the bone than the inner part, whilst the direction of the curve changes towards the edges of the trochlea.

In the apes the articular surface of the inner condyle is very markedly larger than that of the outer condyle, both in breadth and in the extent of its backward curve, which winds upwards on the posterior part of the condyle, so that the articular surface is continued on to its upper aspect. The curve of the outer condyle is much sharper, and the condyle does not project so far backwards; its articular surface is not prolonged so high on the back of the bone. In the apes, therefore, the inner is the more important condyle in the construction of the knee joint, and the marked extension of its articular area backwards and upwards is associated with the position and movements of the knee in flexion. In the ape the thigh is more rotated outwards than in man, and the inner condyle is directed to the front of the limb.

In man there is not nearly the same disproportion in the size of the two condyles as in the apes. I have occasionally seen in man the articular area of the inner broader than that of the outer condyle, but more usually the outer is appreciably the wider. The backward curve of the outer condyle is also prolonged somewhat higher than that of the inner, and thus the condition of the two condyles is the reverse of that found in the ape. It should, however, be stated, as has been shown by Dr. Havelock Charles,[1] that in persons who habitually rest in the squatting position, an upward extension of the articular area of the inner condyle exists, which is associated with the acute flexion of the knee whilst squatting. In man, the outer condyle, when seen in profile, is, as compared with the inner, more elongated antero-posteriorly than in the Gorilla. The approximate equality in the size of the two condyles in man is, without doubt, associated with the extension of the knee joint in the erect attitude, and with the more equable distribution of the weight of the body downwards on the head of the tibia. In the ape the intercondylar fossa, in relation to the size of the bones, is wider in front than in man; but it is wider behind in man than in the ape, for in the latter the inner condyle inclines nearer to the outer condyle than in man.

In man, when the knee joint is extended, the tibia is slightly rotated outwards on the femoral condyles, and the joint is fixed, partly by the tension of the lateral and posterior ligaments and the anterior crucial ligament, and partly by the general tension of the muscles and fasciæ around the joint. So long as these structures remain tense, the joint cannot be bent, and no lateral movement, or rotation, is permitted. The fixation of the joint is of fundamental importance in the act of standing. Free rotation of the human knee can only take place when the joint is acutely bent.

In apes, the joint cannot be fully extended; its natural position, when the animal is standing, is partial flexion, and in this position a limited rotation is permitted, which can be greatly increased when the joint is more completely bent. In rotating the leg on the thigh the inner condyle is apparently the pivot. The rotation facilitates the use of the foot as an organ of prehension, and assists the ape to turn the sole inwards and forwards when holding an object. These movements produce results, which approximate to those occasioned by pronation and supination of the radius on the ulna, in the movements of the forearm and hand.

In the Anthropoid apes, the head of the tibia slopes very decidedly backwards at the upper end of the shaft, so that its axis forms an angle with that of the shaft,

[1] *Journal of Anatomy and Physiology*, vol. xxviii.

and the head may be described as retroverted. If the shaft of the tibia were held vertically, the articular surface for the inner condyle would also slope downwards and backwards, and to a greater degree than that for the outer condyle. But in the natural semiflexed position of the ape's knee the condylar articular surfaces of the tibia are essentially in the horizontal plane.

In the human tibia the axis of the head is, as a rule, almost in line with that of the shaft, and the backward and downward slope of the inner articular surface is not so great as in the ape. In some human tibiæ, however, well-marked retroversion of the head has been seen. In skeletons referred to the Quaternary period of the geologist, this character has been noticed by MM. Collignon, Fraipont, and Testut, and the inference has been drawn that the men of that period could not extend the knee joint and walk as erect as modern man. It has, however, been shown by Professor Manouvrier [1] and Dr. Havelock Charles [2] that this condition of the tibia is not uncommon in some races of men, in whom there can be no question that the attitude is erect when standing. Dr. Charles has associated the production of retroversion to the habit in these races of resting on the ground in the position of squatting. I have found in the tibiæ of the people of the Bronze Age that retroversion of the head of the tibia is not uncommon. In five specimens the backward slope of the head formed with the vertical axis of the shaft an angle which ranged in the several bones from 20° to 30°. But when these tibiæ were put into the erect position alongside of similarly placed modern European bones, the condylar articular surfaces were seen to approximate to the horizontal plane in all the specimens. In order, therefore, that retroversion of the head of the tibia should be associated with inability to extend the knee joint, it is obvious that the articular surfaces should have a marked slope downwards and backwards, as is the case in the Anthropoid apes, when the shaft of the tibia is held in a vertical plane.

I shall now proceed to the examination of the human foot (pes), and in order to bring out more clearly its primary use as an organ of support and progression, I shall contrast it with the human hand (manus) and with the manus and pes in apes. In man, while standing erect, the arched sole of the foot is directed to the ground, and rests behind on the heel and in front on pads, placed below and in line with the metatarso-phalangeal joints, the most important of which is below the joint associated with the great toe. It is therefore a plantigrade foot. The great toe (hallux) lies parallel to the other toes, and from its size and restricted movements gives stability to the foot.

The ape's foot agrees with that of man in possessing similar bones and almost similar soft parts; but it differs materially as to the uses to which it can be put. Some apes can undoubtedly place the sole upon the ground, and in this position use the foot both for support and progression; though the Orang, and to some extent other Anthropoid apes, rest frequently upon the outer edge of the foot. But in addition these animals can use the foot as a prehensile organ like the hand. The old anatomist Tyson, in his description of a young Chimpanzee,[3] spoke of the pes as 'liker a hand than a foot' and introduced the term 'quadrumanous,' four-handed, to designate this character. This term was adopted by Cuvier and applied by him to apes generally, and has long been in popular use. The eminent French anatomist was, however, quite alive to the fact that though the pes was capable of being used as a hand, yet that it was morphologically a foot, so that the term was employed by him to express a physiological character.

In the ape, the great toe, instead of being parallel to the other toes as in man, is set at an angle to them, not unlike the relation which the thumb (pollex) bears to the fingers in the human hand. It is able, therefore, to throw the hallux across the surface of the sole in the prehensile movement of opposition. As it can at the same time bend the other toes towards the sole, it also has the power of encircling an object more or less completely with them. By the joint action of

[1] *Mémoires de la Société d'Anthropologie de Paris*, 1890.
[2] *Journal of Anatomy and Physiology*, vol. xxviii.
[3] *Anatomy of a Pygmie*, 1699, p. 13.

all the toes a powerful grasping organ is produced, more important even than its hand, in which the thumb is feebly developed.

It has sometimes been assumed that the human foot is also a prehensile instrument as well as an organ of support. In a limited sense objects can undoubtedly be grasped by the human toes when bent towards the sole. In savages, this power is preserved to an extent which is not possible in civilised man, in whom, owing to the cramping, and only too frequently the distorting influence, exercised by badly fitting boots and shoes, the proper development of the functional uses of the toes is impeded and their power of independent movement is often destroyed.

Even in savages who have never worn shoes, the power of grasping objects by the toes cannot be regarded as approximately equal in functional activity and usefulness to the range of movement possessed by the ape. The four outer toes are so short and comparatively feeble, that they cannot encircle an object of any magnitude. But, what is even more important, the great toe cannot be opposed to the surface of the sole, in the way that an ape can move its hallux or a man his thumb. Savage man can no doubt pick up an object from the ground with the great toe. Many of us have doubtless seen, among civilised men, persons who have had the misfortune to be born without arms, or who have accidentally lost them in early life, who have trained themselves to hold a pen, pencil, brush, or razor with the foot, and to write, draw, paint, or even shave. But in these cases the object is held between the hallux and the toe lying next to it, and not grasped between the great toe and the sole of the foot by a movement of opposition.

If we compare the anatomical structure of the human foot with that of the foot of the ape, though the bones, joints, and muscles are essentially the same in both, important differences in arrangement may be easily recognised, the value of which will be better appreciated by first glancing at the thumb. Both in man and apes the thumb is not tied to the index digit by an intermediate ligament, which, under the name of 'transverse metacarpal,' binds all the fingers together, and restricts their separation from each other in the transverse plane of the hand. The great toe of the ape, similarly, is not tied to the second toe by a 'transverse metatarsal ligament,' such as connects together and restricts the movements of its four outer toes in the transverse plane of the foot. The hallux of the ape is therefore set free. It can, like the thumb of man and ape, be thrown into the position of opposition and be used as a prehensile digit. Very different is the case in the human foot, in which the hallux is tied to the second toe by a continuation of the same transverse metatarsal ligament which ties the smaller toes together. Hence it is impossible to oppose the great toe to the surface of the sole in the way in which the thumb can be used, and the movements of the digit in the transverse plane of the foot are also greatly restricted.

The development of a connecting transverse band, for the restriction of the movements of the great toe in man, is not the only anatomical structure which differentiates it from the hallux of an ape, or the thumb in the hand. In the manus both of man and apes the joint between the metacarpal bone of the thumb and the bone of the wrist (trapezium) is concavo-convex, or saddle-shaped, and permits of a considerable range of movement in certain directions, and notably the movement of opposition. A joint of a similar configuration, permitting similar movements, is found in the pes of the ape between the metatarsal of the hallux and the tarsal bone with which it articulates. In the foot of man, on the other hand, the corresponding joint is not saddle-shaped, but is almost plane-surfaced, and consequently the range of movement is slight, and is little more than the gliding of one articular surface on the other.

One of the chief factors in the production of the movement of opposition in the manus of man and apes is a special muscle, the opponens pollicis, which, through its insertion into the shaft of the metacarpal bone of the thumb, draws the entire digit across the surface of the palm. In the foot of the Anthropoid apes there is not complete correspondence in different species in the arrangement of the muscles which move the great toe. In the Orang the abductor hallucis, in addition to the customary insertion into the phalanx, may give rise to two slips, one of which is inserted into the base and proximal part of the first metatarsal bone, and the other

into the radial border of its shaft for a limited distance; these slips apparently represent an imperfect opponens muscle, which acts along with the adductor and short flexor muscle of the great toe. In the other Anthropoid apes, the muscle seems to be altogether absent, and the power of opposition is exercised solely by the adductor and the flexor brevis hallucis, the inner head of the latter of which is remarkably well developed.[1] In the human foot there is no opponens hallucis, and the short flexor of the great toe is, in relation to the size of that digit, comparatively feeble, so that no special provision is made for a movement of opposition.

The character and direction of the movements of the digits both in hand and foot are imprinted on the integument of palm and sole. In the palm of the human hand the oblique direction of the movements of the fingers towards the thumb, when bent in grasping an object, is shown by the obliquity of the two great grooves which cross the palm from the root of the index to the root of the little finger. The deep curved groove, extending to the wrist, which marks off the eminence of the ball of the thumb from the rest of the palm, is associated with the opponent action of the thumb, which is so marked in man that the tip of the thumb can be brought in contact with a large part of the palmar surface of the hand and fingers. Faint longitudinal grooves in the palm, situated in a line with the fingers, express slight folds which indicate, where the fingers are approximated to or separated from each other, in adduction and abduction. In some hands a longitudinal groove marks off the muscles of the ball of the little finger from the rest of the palm, and is associated with a slight opponent action of that digit; by the combination of which, with a partial opposition of the thumb, the palm can be hollowed into a cup—the drinking-cup of Diogenes.

These grooves are present in the infant's hands at the time of birth, and I have seen them in an embryo, the spine and head of which were not more than 90 mm. (three and a half inches) long. They appear in the palm months before the infant can put its hand to any use; though it is possible that the muscles of the thumb and fingers do, even in the embryo, exercise some degree of action, especially in the direction of flexion. These grooves are not therefore acquired after birth. It is a question how far the intra-uterine purposeless movements of the digits are sufficient to produce them; but even should this be the case, it is clear that they are to be regarded as hereditary characters transmitted from one generation of human beings to another. They are correlated with the movements of the digits, which give the functional power and range of movement to the hand of man.

In the palm of the hand of the Anthropoid apes grooves are also seen, which differ in various respects from those in man, and which are characteristic of the group in which they are found. In these animals the palm is traversed by at least two grooves from the index border to that of the minimus. In the Gibbon they are oblique, but in the Gorilla, Chimpanzee, and Orang they are almost transverse, which implies that in flexion the fingers do not move so obliquely towards the comparatively feeble thumb as they do in man. The curved groove which limits the ball of the thumb is present, but on account of the less development of that eminence, it is not so extensive as in man. The longitudinal grooves in the palm are deeper than in the human hand, and in the Gorilla and Orang a groove differentiates the eminence associated with the muscles of the little finger from the adjoining part of the palm. The character and direction of these grooves are such as one would associate with the hand of an arboreal animal, in which the long fingers are the chief digits employed in grasping an object more or less cylindrical, like the branch of a tree, and in which the thumb is a subordinate digit. I have not had the opportunity of examining the palm of the embryo of an Anthropoid ape, but in that of an embryo Macaque monkey I have seen both the groove for the ball of the thumb which marks its opposition, and the transverse and longitudinal grooves in the palm which are correlated with the movements of

[1] For a comparative description of the muscles of the hand and foot of the Anthropoid apes consult Dr. Hepburn's memoir in *Journal of Anatomy and Physiology*, vol. xxvi.

the fingers. In apes, therefore, as in man, these grooves are not acquired after birth, but have an hereditary signification.

We may now contrast the grooves in the skin of the sole of the human foot with those which we have just described in the palm. For this purpose the foot of an infant must be selected as well as that of an older person in which the toes have not been cramped and distorted by ill-fitting shoes.[1]

The toes are marked off from the sole proper by a deep diagonal depression, which corresponds with the plane of flexion of the first and second phalanges. Behind this depression, and on the sole proper, is a diagonal groove, which commences at the cleft between the great and second toes, and reaches the outer border of the foot. It is seen in the infant, but disappears as the skin of the foot becomes thickened from use and pressure. This groove marks the plane of flexure of the first phalanges on the metatarsal bones of the four smaller toes. Associated with its inner end is a short groove which curves to the inner border of the foot, and marks off the position of the joint between the first phalanx and the metatarsal bone of the great toe. The groove indicates the movements of the great toe in flexion, and in adduction to, or abduction from, the second toe. It has sometimes erroneously been regarded as the corresponding groove in the foot to the deep curved groove in the hand, which defines the muscles of the ball of the thumb and is associated with the movement of opposition. This is not its real character, for the chief joint concerned in opposition is that between the metacarpal bone and the corresponding carpal bone, and not that between the metacarpal bone and the phalanx. In addition, one, or it may be two faint grooves run from within outwards near the middle of the sole. In the infant's foot a groove also extends longitudinally in the centre of the foot. The grooves on the integument of the sole are in harmony with the inner anatomy of the foot, and confirm the statement, already made, that the great toe in man cannot be opposed to the sole, as the thumb can to the palm, for the great curved groove expressing the movement of opposition is wanting.

In the apes, the condition of the tegumentary grooves in the sole is very different from the human foot. In the Anthropoid group, the ball of the great toe, with its muscles, is marked off by a deep curved groove, which extends from the margin of the cleft between it and the second toe, backwards along the middle of the sole almost as far as the heel. Its depth and extent are associated with the powerful opponent, or grasping action of the hallux. Two other grooves, in front of that just described, pass obliquely across the sole, from the cleft between the hallux and the second toe, and reach the outer border of the foot. They are associated with the movements of the four smaller toes, and their obliquity shows that, when the foot is used as a prehensile organ, the object is grasped not only by the great toe being moved towards the sole, but by the smaller toes being moved towards the hallux. From these arrangements it is obvious that the pes of the ape is, physiologically speaking, a foot-hand, it is pedimanous. Though anatomically a foot, it can be used not only for support and progression, but for prehension, and, for the latter-named office, the hallux is a more potent digit in the foot than is the pollex in the hand. The external rotation of the thigh at the hip joint, and the power of rotating the leg inwards on the thigh at the knee joint, contribute to make the foot of the ape a more important prehensile instrument, and enable the animal to use it more efficiently for this purpose when sitting, than would have been the case if there had been no contributory movements at the hip and knee.

The power of assuming the erect attitude, the specialisation of the upper limbs

[1] These grooves have been described generally by the late Professor Goodsir (*Anatomical Memoirs*, vol. i. 1868); by myself in a lecture on hands and feet, *Health Lectures*, Edinburgh, 1884; and by Mr. Louis Robinson, the last named of whom has called especial attention to their arrangement in the feet of infants (*Nineteenth Century*, vol. xxxi. 1892, p. 795). The integumentary grooves in both hands and feet of men and apes have also been described and figured in detail by Dr. Hepburn in *Journal of Anat. and Phys.*, vol xxvii. 1893, p. 112.

into instruments of prehension, and of the lower limbs into columns of support and progression, are not in themselves sufficient to give that distinction to the human body which we know that it possesses. They must have co-ordinated with them the controlling and directing mechanism placed in the head, known as the brain and organs of sense.

The head, situated at the summit of the spine, holds a commanding position. Owing to the joints for articulation with the atlas vertebra being placed on the under surface of the skull, and not at the back of the head, and to the great reduction in the size of the jaws, as compared with apes and quadrupeds generally, the head is balanced on the top of the spine. The ligaments supporting it and connected with it are comparatively feeble, and do not require for their attachment strong bony ridges on the skull, or massive projecting processes in the spine, such as one finds in apes and many other mammals. The head with the atlas vertebra can be rotated about the axis vertebra by appropriate muscles. The face looks to the front, the axis of vision is horizontal, and the eyes sweep the horizon with comparatively slight muscular effort.

The cranial cavity, with its contained brain, is of absolutely greater volume in man than in any other vertebrate, except in the elephant and in the large whales, in which the huge mass of the body demands the great sensory-motor centres in the brain to be of large size. Relatively also to the mass and weight of the body, the brain in man may be said to be in general heavier than the brains of the lower vertebrates, though it has been stated that some small birds and mammals are exceptions to this rule.

We have abundant evidence of the weight of the brain in Europeans, in whom several thousand brains have been tested. In the men, the average brain-weight is from 49 to 50 oz. (1,390 to 1,418 grm.). In the women, from 44 to 45 oz. (1,248 to 1,283 grm.). The difference in weight is doubtless in part correlated with differences in the mass, weight, and stature of the body in the two sexes, although it seems questionable if the entire difference is capable of this explanation. It is interesting to note that even in new-born children the boys have bigger heads and heavier brains than the girls. Dr. Boyd gives the average for the girl infants as 10 oz., and for boys 11·67 oz. A distinction in the brain weight of the two sexes is obviously established, therefore, before the child is born, and is not to be accounted for by the training and educational advantages enjoyed by the male sex being superior to those of the female sex.

The brains of a number of men of ability and intellectual distinction have been weighed, and ascertained to be from 55 to 60 oz. In a few exceptional cases, as in the brains of Cuvier and Dr. Abercrombie, the weight has been more than 60 oz.; but it should also be stated that brains weighing 60 oz. and upwards have occasionally been obtained from persons who had shown no sign of intellectual eminence.

On the other hand, it has been pointed out by M. Broca and Dr. Thurnam, that if the brain falls below a certain weight it cannot properly discharge its functions. They place this minimum weight for civilised people at 37 oz. for the men, and 32 oz. for the women. These weights are, I think, too high for savage men, more especially in the dwarf races. We may, however, safely assume that if the brain-weight in adults does not reach 30 oz. (851 grm.), it is associated with idiocy or imbecility. There would seem, therefore, to be a minimum brain-weight, which is necessary in order that the mental functions may be actively discharged.

We have unfortunately not much evidence of the weight of the brain in the uncultivated and savage races. The weighings made by Tiedemann, Barkow, Reid, and Peacock give the mean of the brain in the negro as between 44 and 45 oz., a weight which corresponds with that of European women; whilst in the negress the mean weight is less than in the female sex in Europeans. In two Bush girls from South Africa—representatives of a dwarf race—the brain is said to have been 34 and 38 oz. respectively.[1]

From the weighings which have been published of the brains of the Orang and

[1] Sir R. Quain in *Pathological Transactions*, 1850, p. 182, and Messrs. Flower and Murie in *Journal of Anatomy and Phys.*, vol. i. p. 206.

Chimpanzee, it would seem that the brain-weight in these apes ranges from 11 to 15 oz. (312 to 426 grm.), and the brain-weight appears to be much about the same in the Gorilla. These figures are greatly below those of the human brain, even in so degraded a people as the dwarf Bush race of South Africa. They closely approximate to the weight of newly born male infants, in whom, as has just been stated, the average weight was 11·67 oz. For the purposes of ape-life, the low brain-weight is sufficient to enable the animal to perform every function of which it is capable. Its muscular and nervous systems are so accurately co-ordinated that it can move freely from tree to tree, and swing itself to and fro; it can seize and retain objects with great precision, and can search for and procure its food. In all these respects it presents a striking contrast to the infant, having an almost similar brain-weight, which lies helpless on its mother's knee.

Another line of evidence, of which we may avail ourselves, in order to test the relative size of the brain in the different races of men and in the large apes is to be obtained by determining the internal capacity of the cranium. Examples of the brains of different races (except Europeans) are few in number in our collections, but the crania are often well represented, the volume of the cavity in which the brain is lodged can be obtained from them, and an approximate conception of the size and weight of the brain can be estimated. In pursuing this line of inquiry, account has of course to be taken of the space occupied by the membranes investing the brain, by the blood vessels and the cerebro-spinal fluid. A small deduction from the total capacity will have to be made on their behalf.

There is a general consensus of opinion amongst craniologists that the mean internal capacity of the cranium in adult male Europeans is about 1,500 c.c. (91·5 cub. in.). The mean capacity of the cranium of fifty Scotsmen that I have measured by a method, which I described some years ago,[1] was 1,493 c.c. (91·1 cub. in.). The most capacious of these skulls was 1,770 c.c., and the one with the smallest capacity was 1,240 c.c. Thus, in a highly civilised and admittedly intellectual people, the range in the volume of the brain-space amongst the men was as much as 530 c.c. in the specimens under examination, none of which was known or believed to be the skull of an idiot or imbecile, whilst some were known to be the crania of persons of education and position. In twenty-three Scotswomen the mean capacity was 1,325 c.c., and the range of variation was from a maximum 1,625 to a minimum 1,100 c.c.—viz., 525 c.c.

Again I have taken the capacity, by the same method, of a number of crania of the Australian aborigines, a race incapable apparently of intellectual improvement beyond their present low state of development. In thirty-nine men the mean capacity was only 1,280 c.c. (78·1 cub. in.). The maximum capacity was 1,514 c.c., the minimum was 1,044 c.c. The range of variation was 470 c.c. In twenty-four women the mean capacity was 1,115·6 c.c., the maximum being 1,240 and the minimum 930, and the range of variation was 310 c.c. It is noticeable that in this series of sixty-three Australian skulls, all of which are in the Anatomical Museum of the University of Edinburgh, eight men had a smaller capacity than 1,200 c.c., and only four were above 1,400 c.c. Of the women's skulls ten were below 1,100 c.c., four of which were between 900 and 1,000 c.c., and only three were 1,200 c.c. and upwards.

Time does not admit of further detail on the cranial capacities of other races of men. Sufficient has been said to show the wide range which prevails, from the maximum in the Europeans to the minimum in the Australians, and that amongst persons presumably sane and capable of discharging their duties in their respective spheres of activity; for we must assume that the crania of the Australians, having the small capacities just referred to, were yet sufficiently large for the lodgment of brains competent to perform the functions demanded by the life of a savage. From a large number of measurements of capacity which I have made of the skulls of the principal races of men, I would draw the following conclusions: First, that the average cranial capacity, and consequently the volume and weight of the brain, are markedly higher in the civilised European than in the savage races; second, that the range of variation is greater in the former than in the

[1] Human Crania, *Challenger Reports*, Pt. xxix. 1884, p. 9.

latter; third, that in uncivilised man the proportion of male crania having a capacity equal to the European mean, 1,500 c.c., is extremely small; fourth, that though the capacity of the men's skulls is greater than that of the women's, there is not quite the same amount of difference between the sexes in a savage as in a civilised race.

It may now be of interest to say a few words on the capacity of the cranium in the large anthropoid apes. I have measured, by the method already referred to, the capacity of the skulls of five adult male Gorillas, and obtained a mean of 494 c.c., the maximum being 590 c.c. and the minimum 410 c.c., the range of variation being 180 c.c. Dr. Delisle found the old male Orang (Maurice),[1] which died a short time ago in the Jardin des Plantes, to have a capacity of 385 c.c., whilst the younger male (Max) had a capacity of 470 c.c.[2] The mean of eleven specimens measured by him was 408 c.c., which is somewhat less than the measurements of males recorded by M. Topinard and Dr. Vogt; but it should be stated that in some of Dr. Delisle's specimens the sex could not be properly discriminated, and possibly some of them may have been females. The cranial capacity of seven male Chimpanzees is stated by M. Topinard to be 421 c.c.

The determination of the mass and weight of the brain as expressed in ounces, and of the capacity of the cranial cavity as expressed in cubic centimetres, are only rough methods of comparing brain with brain, either as between different races of men, or as between men and other mammals. Much finer methods are needed in order to obtain a more exact comparison.

The school of Phrenologists represented in the first half of the century by Gall, Spurzheim, and George Combe, whilst recognising the importance of the size of the brain as a measure of intellectual activity, also attached value to what was called its quality. At that time the inner mechanism of the brain was almost unknown, for the methods had not been discovered by which its minute structure could be determined. It is true that a difference was acknowledged, between the cortical grey matter situated on the surface of the hemispheres and the subjacent white matter. Spurzheim had also succeeded in determining the presence of fibres in the white matter of the encephalon, and had, to a slight extent, traced their path. The difference between the smooth surface of the hemispheres of the lower mammals and the convoluted surface of the brain of man and the higher mammals, and the influence which the development of the convolutions exercised in increasing the area of the cortical grey matter, were also known.

A most important step in advance was made, when, through the investigations of Leuret and Gratiolet, it became clear that the convolutions of the cerebrum, in their mode of arrangement, were not uniform in the orders of mammals which possessed convoluted brains, but that different patterns existed in the orders examined. By his further researches Gratiolet determined that in the anthropoid apes, notwithstanding their much smaller brains, the same general plan of arrangement existed as in man, though differences occurred in many of the details, and that the key to unlock the complex arrangements in man was to be obtained by the study of the simpler disposition in the apes. These researches have enabled anatomists to localise the convolutions and the fissures which separate them from each other, and to apply to them precise descriptive terms. These investigations were necessarily preliminary to the histological study of the convolutions, and to experimental inquiry into their functions.

By the employment of the refined histological methods now in use, it has been shown that the grey matter in the cortex of the hemispheres, and in other parts of the brain, is the seat of enormous numbers of nerve-cells, and that those in the cortex, whilst possessing a characteristic pyramidal shape, present many variations in size. Further, that these nerve-cells give origin to nerve axial fibres, through which areas in the cortex become connected directly or indirectly, either with other areas in the same hemisphere, with parts of the brain and spinal cord situated below the cerebrum, with the muscular system, or with the skin and other organs of sense.

[1] *Nouvelles Archives du Muséum d'Histoire naturelle*, 1895.

[2] The stature of Maurice was 1 m.·40; that of Max 1 m.·28.

Every nerve-cell, with the nerve axial fibre arising from and belonging to it, is now called a Neurone, and both brain and spinal cord are built up of tens of thousands of such neurones. It may reasonably be assumed that the larger the brain the more numerous are the neurones which enter into its constitution. The greater the number of the neurones, and the more complete the connections which the several areas have with each other through their axial fibres, the more complex becomes the internal mechanism, and the more perfect the structure of the organ. We may reasonably assume that this perfection of structure finds its highest manifestations in the brain of civilised men.

The specialisation in the relations and connections of the axial fibre processes of the neurones, at their termination in particular localities, obviously points to functional differences in the cortical and other areas, to which these processes extend. It has now been experimentally demonstrated that the cortex of the cerebrum is not, as M. Flourens conceived, of the same physiological value throughout; but that particular functions are localised in definite areas and convolutions. In speaking of localisation of function in the cerebrum, one must not be understood as adopting the theory of Gall, that the mental faculties were definite in their number, that each had its seat in a particular region of the cortex, and that the locus of this region was marked on the surface of the skull and head by a more or less prominent 'bump.'

The foundation of a scientific basis for localisation dates from 1870, when Fritsch and Hitzig announced that definite movements followed the application of electrical stimulation to definite areas of the cortex in dogs. The indication thus given was at once seized upon by David Ferrier, who explored not only the hemispheres of dogs, but those of monkeys and other vertebrates.[1] By his researches and those of many subsequent inquirers, of whom amongst our own countrymen we may especially name Beevor, Horsley, and Schäfer, it has now been established that, when the convolutions bounding, and in close proximity to the fissure of Rolando are stimulated, motor reactions in the limbs, trunk, head and face follow, which have a definite purposive character, corresponding with the volitional movements of the animal. The Rolandic region is therefore regarded as a part of the motor apparatus; it is called the motor area, and the function of exciting voluntary movements is localised in its cortical grey matter.

By the researches of the same and other inquirers it has been determined that certain other convolutions are related to the different forms of sensibility, and are sensory or perceptive centres, localised for sight, hearing, taste, smell, and touch.

Most important observations on the paths of conduction of sensory impressions in the cortex of the convolutions were announced last year by Dr. Flechsig,[2] of Leipzig, so well known by his researches on the development of the tracts of nerve-fibres in the columns of the spinal cord, published several years ago. He discovered that the nerve-fibres in the cord did not become myelinated, *i.e.* attain their perfect structure, at a uniform period of time, so that some acquired their complete functional importance before others. He has now applied the same method of research to the study of the development of the human brain, and has shown that in it also there is a difference in the time of attaining perfect structural development of the nerve-tracts. Further, he has discovered that the nerve-fibres in the cerebrum become myelinated, subsequent to the fibres of the other divisions of the cerebro-spinal nervous axis. When a child is born, very few of the fibres of its cerebrum are myelinated, and we have now an anatomical explanation of the reason why an infant has so inactive a brain and is so helpless a creature. It will therefore be of especial interest to determine, whether in those animals which are active as soon as they are born, and which can at once assume the characteristic attitude of the species, the fibres of the cerebrum are completely developed at the time of birth. Flechsig has also shown that the sensory paths myelinate before the motor tracts; that the paths of transmission of touch, and the other impulses conducted by the dorsal roots of the spinal nerves, are

[1] *West Riding Asylum Reports*, 1873.
[2] *Die Localisation der Geistigen Vorgänge*, Leipzig, 1896.

the first to become completely formed, whilst the fibres for auditory impulses are the last.

Flechsig names the great sensory centre which receives the impulses associated with touch, pain, temperature, muscular sense, &c., *Körperfühlsphäre*, the region of general-body-sensation, or the somæsthetic area as translated by Dr. Barker.[1] The tracts conducting these impulses myelinate at successive periods after birth. They pass upwards from the inner and outer capsules and the optic thalamus as three systems.[2] Some enter the central convolutions of the Rolandic area, others reach the paracentral lobule, the inferior frontal convolution, the insula, and small parts of the middle and superior frontal convolutions; whilst considerable numbers reach the gyrus fornicatus and the hippocampal gyrus, which Ferrier had previously localised as a centre of common or tactile sensibility.

The Rolandic area, therefore, is not exclusively a motor area, but is a centre associated also with the general sensibility of the body. The motor fibres in it are not myelinated until after the sensory paths have become developed. As the motor paths become structurally complete, they can be traced downwards as the great pyramidal tract from the pyramidal nerve-cells in this area, from which they arise, into the spinal cord, where they come into close relation with the nerve-cells in the anterior horn of grey matter, from which the nerve axial fibres proceed that are distributed to the voluntary muscles.

Flechsig's observations agree with those of previous observers in placing the visual centre in the occipital lobe; the auditory centre in and near the superior temporal convolution; and the olfactory centre in the uncinate and hippocampal convolutions. Of the position of the taste centre he does not speak definitely, although he thinks it to be in proximity either to the centre of general sensation, or to the olfactory centre.

The centres of special sense in the cortex, and the large Rolandic area, which is the centre both for motion and general sensation, do not collectively occupy so much as one-half of the superficial area of the convolutions of the cortex. In all the lobes of the brain—frontal, parietal, occipito-temporal, and insula—convolutions are situated, not directly associated with the reception of sensory impressions, or as centres of motor activity, the function of which is to be otherwise accounted for. These convolutions lie intermediary to the sensory and motor centres. Flechsig has shown that in them myelination of the nerve-fibres does not take place until some weeks after birth, so that they are distinctly later in acquiring their structural perfection and functional activity. As the nerve-fibres become differentiated, they are seen to pass from the sense-centres into these intermediate convolutions, so as to connect adjacent centres together, and bring them into association with each other.[3] Hence he has called them the Association centres, the function of which is to connect together centres and convolutions otherwise disconnected.[4]

We have now, therefore, direct anatomical evidence, based upon differences in their stages of development, that, in addition to the sensory and motor areas in the

[1] *Johns Hopkins Bulletin*, No. 70, January 1897.

[2] Drs. Ferrier and Aldren Turner communicated to the Royal Society of London a few weeks ago (*Proc. R.S.* June 17, 1897) an account of an elaborate research on the tracts which convey general and special sensibility to the cerebral cortex of monkeys. Their results were obtained by the aid of destructive lesions and the study of the consecutive degenerations in the nerve-tracts. From the brief abstract in the *Proceedings*, their research, though conducted by a different method, harmonises with the observations of Flechsig on the human brain, in regard to the course and connections of the great thalamic cortico-petal sensory fibres. They have also traced association fibres in connection with both the visual and auditory systems.

[3] The term association fibres was introduced a number of years ago to express fibres of the cerebrum which connect together parts of the cortex in the same hemisphere. Flechsig's fibres belong to this system.

[4] The Association centres had previously been referred to by other observers as 'silent portions' of the cortex, not responding to electrical stimulus. Their possible function had been discussed by Professor Calderwood in *Relations of Mind and Brain*, 2nd edit., 1884.

cortex of the human brain, a third division—the association centres—is to be distinguished.

If we compare the cerebrum in man and the apes, we find those convolutions which constitute the motor and sensory centres distinctly marked in both. An ape, like a man, can see, hear, taste, smell and touch; it also exhibits great muscular activity and variety of movement. It possesses, therefore, similar fundamental centres of sensation and motion, which are situated in areas of the cortex, resembling in arrangement and relative position, though much smaller in size than, the corresponding convolutions in the adult human brain. It is not unlikely, though the subject needs additional research, that the minute structure of these centres resembles that of man, though, from the comparatively restricted area of grey matter in the ape, the neurones will necessarily be much fewer in number.

In the cerebrum of a new-born infant, whilst the motor and sensory convolutions are distinct, the convolutions for the association areas, though present, are comparatively simple, and do not possess as many windings as are to be seen in the brain of a chimpanzee not more than three or four years old.

Again, if we compare the brain of the Bushwoman, miscalled the Hottentot Venus, figured by Gratiolet and by Bischoff, or the one studied by Mr. John Marshall, with that of the philosopher Gauss, figured by Rudolph Wagner, we also recognise the convolutions in which the motor and sensory areas are situated. In all these brains they have a comparative simplicity of form and arrangement which enables one readily to discriminate them. When we turn, however, to the association areas in the three tiers of convolutions in the frontal lobe, and in the parieto-occipital and occipito-temporal regions where the bridging or annectant convolutions are placed, we cannot fail to observe that in a highly-developed brain, like that of Gauss, the association convolutions have a complexity in arrangement, and an extent of cortical surface much more marked than in the Bushwoman, and to a still greater degree than in the ape. The naked-eye anatomy of the brain therefore obviously points to the conclusion that these association areas are of great physiological importance.

The problem which has now to be solved is the determination of their function. Prolonged investigation into the development and comparative histology of the brain will be necessary before we can reach a sound anatomical basis on which to found satisfactory conclusions. It will especially be necessary to study the successive periods of development of the nerve-fibre tracts in the cerebrum of apes and other mammals, as well as the magnitude and intimate structure of the association areas in relation to that of the motor and sensory areas in the same species.

Flechsig, however, has not hesitated to ascribe to the association centres functions of the highest order. He believes them to be parts of the cerebral cortex engaged in the manifestations of the higher intelligence, such as memory, judgment, and reflection; but in the present state of our knowledge such conclusions are of course quite speculative.

It is not unlikely, however, that the impulses which are conveyed by the intermediate nerve-tracts, either on the one hand, from the sense centres to the association centres, or on the other, from the association centres to the sensory and motor centres, are neither motor nor sensory impulses, but a form of nerve energy, determined by the terminal connections and contacts of the nerve fibres. It is possible that the association centres, with the intermediate connecting tracts, may serve to harmonise and control the centres for the reception of sensory impressions that we translate into consciousness, with those which excite motor activity, so as to give to the brain a completeness and perfection of structural mechanism, which without them it could not have possessed.

We know that an animal is guided by its instincts, through which it provides for its individual wants, and fulfils its place in nature. In man, on the other hand, the instinctive acts are under the influence of the reason and intelligence, and it is possible that the association centres, with the intermediate association fibres which connect them with the sensory and motor centres, may be the mechanism through which man is enabled to control his animal instincts, so far as they are dependent on motion and sensation.

The higher we ascend in the scale of humanity, the more perfect does this control become, and the more do the instincts, emotions, passions and appetites become subordinated to the self-conscious principle which regulates our judgments and beliefs. It will therefore now be a matter for scientific inquiry to determine, as far as the anatomical conditions will permit, the proportion which the association centres bear to the other centres both in mammals and in man, the period of development of the association fibres, in comparison with that of the motor and sensory fibres in different animals, and, if possible, to obtain a comparison in these respects between the brains of savages and those of men of a high order of intelligence.

The capability of erecting the trunk; the power of extending and fixing the hip and knee joints when standing; the stability of the foot; the range and variety of movement of the joints of the upper limb; the balancing of the head on the summit of the spine; the mass and weight of the brain, and the perfection of its internal mechanism, are distinctively human characters. They are the factors concerned in adapting the body of man, under the guidance of reason, intelligence, the sense of responsibility and power of self-control, for the discharge of varied and important duties in relation to himself, his Maker, his fellows, the animal world and the earth on which he lives.

THURSDAY, AUGUST 19.

The following Papers and Reports were read:—

1. *The Scalp-lock: a Study of Omaha Ritual.* *By* Miss ALICE C. FLETCHER.

[Published in *Journ. Anthrop. Institute,* No. 102, February 1898.]

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2. *The Import of the Totem among the Omaha.* *By* Miss ALICE C. FLETCHER.

[Published separately Salem, Mass., 1897.]

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3. *Squaktktquaclt, or the Benign-faced Oannes of the Ntlakapamuq, British Columbia.* *By* C. HILL-TOUT.

Squaktktquaclt, or Benign-face, the mythological hero of the Ntlakapamuq, B.C., is the youngest son of the red-headed woodpecker by his favourite wife, the black bear woman. The grizzly woman, his other wife, became jealous of the black bear, and killed both her and her husband by treachery, and would have also killed the black bear's three sons, but they ran away. They were pursued by the grizzly, who met her death in the pursuit. The three boys wandered about the country, the youngest, *Squaktktquaclt,* becoming a powerful but kind-hearted shaman, who used his power in alleviating the misery and misfortunes of the people and in punishing by metamorphosis the evildoers. He also teaches the people many useful arts, and otherwise instructs them. He is to the Ntlakapamuq what *Skīlāp* is to the Shushwaps, and seems indeed to be the same personage. He also recalls the 'Great Transformer' of the Kwakiutl.

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4. *The Blackfoot Legend of Scar-face.* *By* R. N. WILSON.

The legend of Uk-ske, or Scar-face, is believed by the Algonquian Blackfeet to explain the origin of their principal sacred ceremonies and beliefs. So much ritual has reference to this myth, and so many observances are founded upon it, that the

student of Indian religious thought may accept it as one of the most significant and instructive legends possessed by these tribes.

A very beautiful young Indian woman refused all her suitors, but promised a young man, who was disfigured by a scar, that she would marry him when the scar disappeared from his face. After a long journey to the East he came to where the Sun lived with his wife, the Moon. Their son, the Morning Star, took pity on Scar-face, and they ultimately became great friends. The Sun cured Scar-face and kept him for a year in order to teach him religious ceremonies. Eventually Scar-face returned home and married the girl. The great religious ceremonies of the Blackfeet, having first been performed under the direction of Scar-face, were practised every year after that, and the Sun, as he had promised, was kind to the people and heard their prayers.

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5. *Blackfoot Sun-offerings.* *By* R. N. WILSON.

In the neighbourhood of Indian camps and reservations a familiar sight is an article of clothing, such as a coat, shirt, or blanket attached to a stick and placed in a conspicuous position, or tied to the trunk of a prominent tree. These are sacrificial offerings to the Sun, which in former times consisted of the rarest and most highly valued articles possessed by the Indians. Of the numerous objects of worship the Sun is the one which receives the greatest amount of adoration. More prayers are addressed to this principal deity than to all of the others combined, and the most important of the religious rites and ceremonies are devoted to him in particular. When a Blackfoot is asked why such rites are practised in worship of the Sun, he replies, 'Because Scar-face taught us so.' Although the Sun is now, and has doubtless for centuries been, pre-eminently the Blackfoot divinity, it may be that they have or had more ancient deities. The Sun is then the principal deity. Every middle-aged Indian in the three tribes knows that the 'Creator' was never heard of by them until the advent of the missionaries. Equally erroneous is the view that they addressed prayers to, or in any manner worshipped, 'Napi,' the Old Man of the legends, the blunderer, the immoral mischief-maker. The details of the rites of sacrificing to the Sun cannot, do not, readily admit of condensation. It is to be hoped that these two papers of Mr. Wilson's will be published in full by the Anthropological Institute.

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6. *Star-lore of the Micmacs of Nova Scotia.* *By* STANSBURY HAGAR.

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7. *The Lake Village of Glastonbury and its Place among the Lake-dwellings of Europe.* *By* DR. R. MUNRO.—See Reports for 1893–96.

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8. *Report on the Silchester Excavations.*—See Reports, p. 511.

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9. *Some Old-world Harvest Customs.* *By* F. T. ELWORTHY.

The author described and illustrated examples of corn charms, harvest trophies from Egypt and Thessaly, of the oaten *Clyach*, or corn-baby, and the Kirnmaiden from Aberdeen, Elgin, East Lothian, and Forfarshire; the *Casez Ved* from Cardiganshire; and of the *Neck* from Devonshire, and discussed their significance as survivals of an animistic corn-cult.

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10. *Report on the North Dravidian and Kolarian Races of Central India.* See Reports, p. 427.

FRIDAY, AUGUST 20.

The President's Address was delivered.—See p. 768.

The following Papers and Reports were read:—

1. *A Demonstration of the Utility of the Spinal Curves in Man. By* Professor ANDERSON STUART.

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2. *The Cause of Brachycephaly. By* Professor A. MACALISTER, *F.R.S.*

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3. *Notes on the Brains of some Australian Natives. By* Professor A. MACALISTER.

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4. *On some Cases of Trepanning in Early American Skulls. By* Dr. W. J. MCGEE.

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5. *A Case of Trepanning in North-Western Mexico. By* W. CARL LUMHOLTZ *and* Dr. A. HRDLICKA.

The trepanned skull[1] was found in a burial cave known to the Tarahumare Indians of the Pino Gordo section of the Sierra Madre, about one and a half days north of Guadalupe y Calvo. Three skeletons were found, lying in Tarahumare fashion, on their backs, with the faces to the east, and accompanied by a few crude native clay vessels. The trepanned skull is that of an aged female, a little more massive than the native average, to all appearance not pre-Columbian, but at the same time not recent, for a spindle wheel found with it is not of recent type The skull presents no deformity or fracture, but signs of an old superficial injury at about the middle of the junction of the right parietal with the occipital.

The opening in the skull lies in the anterior and superior part of the right parietal bone, 1·3 cm. behind the coronal and 2·3 cm. below the sagittal suture. It is almost exactly round, measuring 2 cm. in diameter: the outer edge is smooth and somewhat sunken, the inner obscured by a lamella of thin bone from all parts of the inner edge to the centre, and whose free edge is very sharp and irregular. Seen from within this skull the lamella appears smooth and directly continuous with the inner skull surface. There seems no doubt that part, at least, of this lamella remained after the wound had been made.

The walls of the opening are quite smooth, and covered with a compact bony tissue. This fact, in connection with the smooth and slightly sunken external edge, shows that the wound had been made a long time—several years before the death of the person.

The almost circular form of the opening and its perpendicular walls, which show no signs of bevelling, do not admit of the supposition that it was produced by scraping. One is forced to believe that it was produced by a kind of flint wimble with three teeth, very much like the instruments of iron used to-day in trepanning by the Berbers of l'Aurés.[2] At present the Tarahumares have no such tool, and, moreover, no knowledge of the operation of trepanning.

NOTE.—Since the above was read another instance of trepanning in the same

[1] *Am. Mus. Nat. Hist.* (New York), Lumholtz Coll., No. $\frac{97}{39}$.

[2] Drs. Malbot and Verneau, 'Les Chaouias et la trépanation du crâne dans l'Aurés,' *Revue d'Anthropologie*, 1897, ii. figs. 1-3.

region has come to the notice of the authors. This second skull (which also is in the Lumholtz Collection, and is deposited at the Museum of the University of Pennsylvania) is in many respects similar to the first described specimen. It is also a female skull, and the trepanning is situated in almost the identical spot as in the first case. The two specimens will be described in detail in one of the coming numbers of the 'Amer. Anthropologist' published at Washington.

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6. *Report on the Mental and Physical Deviations in Children from the Normal.*—See Reports, p. 427.

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7. *Report on Anthropometric Measurements in Schools.* See Reports, p. 451.

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8. *An Experimental Analysis of certain Correlations of Mental Physical Reactions. By* Professor LIGHTNER WITMER.

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9. *The Growth of Toronto School Children. By* Dr. FRANZ BOAS. See Report on the Ethnological Survey of Canada, p. 443.

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10. *The Physical Characteristics of European Colonists born in New Zealand. By* Dr. H. O. FORBES.

SATURDAY, AUGUST 21.

The Section did not meet.

MONDAY, AUGUST 23.

The following Reports and Papers were read :—

1. *Report on the North-Western Tribes of Canada.*

The publication of this Report is deferred until next year, when the final Report of the Committee will be presented.

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2. *The Seri Indians of the Gulf of California. By* Dr. W. J. McGEE.

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3. *Historical and Philological Notes on the Indians of British Columbia. By* C. HILL-TOUT.

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4. *The Kootenays and their Salishan Neighbours.*

By Dr. A. F. CHAMBERLAIN, *Clark University, Worcester, Mass.*

The chief results of the investigations carried on amongst the Kootenays of South-eastern British Columbia by the writer in 1891 have appeared in the Report of the British Association for 1892, but the material then obtained is still being studied, especially the linguistic data. An ethnological sketch of the Shushwaps, neighbours of the Kootenays on the west, who belong to the Salishan linguistic stock, was published by Dr. G. M. Dawson, in the 'Transactions' of the Royal Society of Canada for 1891, and another brief account of them, by Dr. Franz Boas, appeared in the Report of the British Association for 1890. It is upon these that the comparisons here made are based. In respect of languages these adjacent peoples show marked differences: the Kootenay makes very little use of reduplication (none, seemingly, for grammatical purposes), possesses incorporation in a manner similar to the Nahuatl of Mexico, and verbal composition like the Sionan and the Athapascan languages. The Shushwap employs reduplication extensively and has 'substantivals' like the Algonkian tongues. The general linguistic affinities of the Kootenay seem to lie, perhaps with the Shoshonian stock, though nothing definite has yet been made out, and it still remains an independent family of speech. The general affinities of the Shushwap are more with the Kwakiutl-Nootka. Of borrowings between Kootenay and the Salishan languages there have been few. *StatlEm*, 'a dug-out,' *háEtltsin*, 'a dog,' *kátltsa*, 'four,' finding cognates in Salishan dialects; also, perhaps, the words for 'four,' and 'eight.' In certain arts, implements, &c., sweat-houses, fire-baking of roots, pine-bark fuel, root-foods games, the likeness between the two peoples, even in detail, is very close, the affinity lying, however, sometimes with peoples north of them, sometimes with those to the south, the Kootenays favouring the latter, the Shushwap the former. A peculiar pipe figured by Dawson, and 'differing in shape from any hitherto seen by me in British Columbia,' closely resembles one found among the Kootenays, who also possess the pestle-shaped hammer of the Shushwaps and coast tribes. By far the most noteworthy coincidence, however, is the possession by the Kootenays and the Shushwaps of the peculiar double (downwards) pointed bark-canoe, of the kind which Professor O. T. Mason calls the Amoor type, since it is found also on that Asiatic river. The Kootenay name *yāktsōmitl* differs entirely from the Salishan names, and its use with them is much more common than with the Shushwaps. Hence one might reasonably argue that the borrowing here has been from the Kootenays on the part of the Shushwaps, and not *vice versa*. The fish-traps and fish-weirs of the two peoples are practically identical. In their social organisation the two peoples resemble each other in their lack of gentes and complicated secret societies. More evidences of sun-worship are found with the Kootenays than with the Shushwaps. In mythological *fond* there are striking resemblances especially in the animal tales, where the coyote (indicative of southern affinities) performs a chief *rôle*, though with the Kootenays he is not *the* hero as with the Shushwaps.

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5. *Kootenay Indian Drawings.*

By Dr. A. F. CHAMBERLAIN, *Clark University, Worcester, Mass.*

The author exhibited some 300 drawings of natural objects, animals, implements, human beings, &c., which he obtained in the summer of 1891 from certain members of the Kootenay tribe of South-eastern British Columbia, to whom he had given, for the purpose, paper and pencils. None of the Indians whose genius the drawings represent had ever, so far as known, received any instruction in the art from the whites, and the skill displayed is even more noteworthy, when we consider the fact that no rock carvings or picture-writings are on record from the region in question.

In the delineations of celestial and terrestrial phenomena the most remarkable points are the depicting of the clouds as masses dependent from the arch of the

sky, or resting on the mountains, and the ability shown in map-drawing, the course of the Kootenay and Columbia Rivers, the lake expansions, and the tributary streams being properly indicated. These Indians readily recognise on a map the chief topographical features of their country. Of 188 figures of animals, birds, reptiles, fish, &c., all but two (both owls) are in profile, while of thirty-five human figures, seven only are in profile, and of these four are by one Indian and three by another. Of the animal figures eighty-three distinctly face the right, ninety-two the left; of the seven human profiles two are right, five left. The characteristic attitudes of such creatures as the buffalo, the bear, the coyote, the rabbit, the otter, the beaver, the horse, squirrel, salmon, swallow, humming-bird, woodpecker, owl, are represented, and the distinctive marks of the male and female horned animals, tails and beaks of birds, and the like denoted. The same is the case with the figures representing men and women of various Indian tribes.

As the drawings represent the efforts of Indians of various ages from eighteen to sixty, there is a great range of difference in the merit of the productions, some, especially those of the oldest artist, being made almost to caricature, while some drawings of buffaloes, bears, horses, and especially steamboats by the younger Indians evidence marked ability, and compare favourably with the efforts of very many adult whites. In complexity the drawings range from the simple delineation of a fish-hook or an arrow-point to the depicting of a steamboat at anchor in the river, or a buffalo hunt—this last a remarkable piece of work—and a gambling-scene, in the delineation of which conventionalising appears. Another interesting picture is that of a war-dance; and it may be worth noting here that when the old Indian artist who drew it had concluded his work the force of association was too much for him, and holding the paper aloft in his hand he exemplified for a few moments what the picture represents.

The marked abilities of the Kootenays in drawing go with their noticeably high mental character, which has been noted by all observers from De Smet to the present time. As compared with the drawings of children these Indian pictures emphasise the difference between the art of primitive races, with their sharp observation gift, and the self-scribblings, imperfect copyings, and crude imaginings. With the savage art is beginning to be an art; with the child it lingers long as an amusement.

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6. *A Rock Inscription on Great Central Lake, Vancouver Island.* *By* J. W. MacKay.

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7. *Blackfoot Womanhood.* *By* Rev. John Maclean, *M.A., Ph.D.*

The imperfection of woman and her position of inferiority are emphasised in the legends of the Blackfeet. Girls are trained by the women in the duties of camp life. The loose style of dress worn begets freedom of motion, and influences the physical form. The outdoor life induces health, yet early marriage, harsh treatment, the use of tobacco, the smoke of the lodges, and the lack of ambition bring premature physical and mental decay. The women prepared the hides of the buffalo for sale, pitched the lodges and took them down, and the first wife retained supremacy in the lodge. The internal arrangements of all the lodges are similar. Log houses have replaced the lodges of buffalo-skin since the people settled on reservations and the buffalo has disappeared. Civilisation has introduced cooking utensils and modified methods of cooking materially affecting the health of the people. The women gather the berries, pound them between stones, and put them up in skin-bags for winter use. They wash themselves by filling their mouths with water, squirting it into their hands, and rubbing their faces and hair with their hands. Striking the hair with the hands supplies the place of a comb. The artistic skill of the women is shown in making moccasins, fire-bags, leggings, and leather shirts, the designs being wrought with beads, dyed porcupine quills, and silk thread of various colours. The Blackfoot women are

not as expert as the Northern Cree women at this kind of work. There is a natural division of labour between the sexes. Agriculture is a new occupation for these hunting tribes. The ordinary costume of the women consists of a loose gown of equal width from top to bottom without fastenings of any kind, having wide sleeves, a pair of leggings and moccasins, and an outer blanket or skin. Brass rings on each finger of both hands, earrings, and necklace and painted face serve as ornaments. Napioa instituted marriage. The females are married early, sometimes at eleven or twelve years of age. Marriage is by purchase. War between tribes destroyed the men and left a large majority of women, and polygamy arose. Nature is putting an end to polygamy through an equalising of the sexes. Divorce is an easy matter. Adultery is punished by cutting off the woman's nose. Twins are considered a calamity. There are medicine-women who are not members of the medical priesthood. The women are modest, love their children intensely, obey their husbands, quarrel with the other members of the lodge, ride horseback in the same fashion as men, smoke as men, but use common pipes and smoke separately, not in unison as the men; are good swimmers, throwing the hands in dog fashion; mourn deeply when one of their dogs is killed, drink tea incessantly, are inveterate gamblers. Since coming in contact with civilisation many of the women have become immoral. Cree and Kootenay women are sometimes found married to Blackfoot husbands. The women are sweet singers. In the native dances they dance separately. The females prepare the corpses of their deceased relatives for burial, are the chief mourners at funerals, prepare the sacred tongues for the sun-dance.

Mythology affects the status of woman. Harsh treatment, early marriage, and poverty induce premature physical and mental decay. Cooking exerts a strong influence on the health and longevity of individuals. Totemism affects the modes of life and thought of the people. Polygamy is dependent on tribal wars. Civilisation injures the morals of the aborigines.

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8. *On the Hut-burial of the American Aborigines.* *By* E. SIDNEY HARTLAND.

James Adair, whose 'History of the American Indians' was published in 1775, describes the burial of natives belonging to the Cherokees and allied tribes as taking place in their own huts. The deceased was buried within his own house, under the widow's bed. The same custom was found by the Spaniards among certain tribes of South America, and it has continued to the present day in Brazil. Traces also remain of it among the Zuñis. Nor is it peculiar to the American continent; at one time it was even the practice of the ancestors of the European peoples. Its origin must be sought for in the savage idea of kinship, and in the desire to retain within the kin the deceased, with all his power and virtues. As civilisation developed, however, the inconveniences of keeping the dead, either above or below ground, in the hut which continued to be the dwelling of the survivors began to be perceived. Various expedients were devised to obviate these inconveniences. Many people preserved the desiccated bones of the dead, which were often, as among many of the North American tribes, finally deposited in gentile ossuaries.

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Unter den Naturvölkern Zentral-Brasiliens, Reiseschilderung und Ergebnisse der zweiten Schingú-Expedition, 1887–1888. Von Karl von den Steinen, Prof. Dr., Berlin, 1894.

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Ancient Society; or, Researches in the Lives of Human Progress from Savagery through Barbarism to Civilisation. By LEWIS H. MORGAN, LL.D. London, 1877.

Die Gebräuche und religiösen Anschauungen der Kekchí-Indianer. Von Dr. CARL SAPPER, Guatemala. In viii. *Internat. Archiv für Ethnographie.* Leiden, 1895.

Tribes of the Extreme North-West. By W. H. DALL in i. *Contributions to N. Am. Ethnology.* Washington, 1877.

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9. *Report on the Ethnological Survey of Canada.*—See Reports, p. 440.

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10. *The Origin of the French Canadians.* *By* B. SULTE.

See Report on the Ethnological Survey of Canada, p. 440.

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11. *Report on the Ethnographical Survey of the United Kingdom.*

See Reports, p. 452.

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12. *The Evolution of the Cart and Irish Car.* *By* Professsor A. C. HADDON.

TUESDAY, AUGUST 24.

The following Papers and Report were read:—

1. *The Jesup Expedition to the North Pacific.* *By* Professor F. W. PUTNAM.

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2. *Discussion of Evidences of American-Asiatic Contact.*

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3. *Why Human Progress is by Leaps.* *By* GEORGE ILES.

We are accustomed to regard the decisive triumphs of man as he wins each one of them as simple additions to his resources, material and mental, whereas in truth they are multipliers of high potency, entering as they do into wide and fruitful union with the talents and powers they find already in the field. The introduction of every invention or discovery of prime dignity at once tends to quicken the pace of progress to a leap. It would appear that the distinction between a multiplier and an addition, as each supreme victory comes to human wit, sheds light on three cardinal facts regarding man. First, his comparatively rapid development from animality. Second, his separation to-day from his next of kin by a gulf more profound and wide than that between any two other allied families in all nature. Third, his advance, when civilised, in power and faculty at a pace ever accelerated.

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4. *On the Transmission of Acquired Characters.* *By* Professor J. COSSAR EWART, *F.R.S.*

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5. *On the Kafirs of Kafiristan.* *By* Sir GEORGE ROBERTSON, *K.C.S.I.*

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6 *On the Mangyans and Tagbanuas of the Philippine Isles.* *By* Professor DEAN C. WORCESTER.

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7. *Report on the Necessity of the Immediate Investigation of the Anthropology of Oceanic Islands.*—See Reports, p. 352.

WEDNESDAY, AUGUST 25.

A joint discussion with Section C (Geology) on the first Traces of Man in the New World was introduced by the reading of the following Papers:—

a. *The Trenton Gravels.* *By* Professor F. W. PUTNAM.
b. *Human Relics in the Drift of Ohio.* *By* Professor E. W. CLAYPOLE.

The following Papers were read:—

1. *On some Spear-heads made of Glass from West Australia.* *By the President of the Section,* Sir W. TURNER, *F.R.S., F.R.S.E.*

In July of this year I received from Dr. G. Archdall Reid three specimens of spear heads, which had recently been brought by Mr. Robert Grant from Roebuck Bay, West Australia. They had been made by the natives from glass bottles thrown into the bush by the English settlers in that locality. Two were made of coloured glass, as if from beer bottles, and one from white glass. That from white glass was 96 mm. long and 30 mm. in its widest part, whilst the others were 91 mm. and 81 mm. long respectively. They were sharply pointed at one end, whilst the opposite end was in two instances finished with a convex border and in the third with a straight base. The margins were serrated, and the surfaces showed the marks where flakes of glass had been removed during the manufacture of the spear head. Mr. Grant has seen the natives engaged in the manufacture of these implements. He states that the piece of glass rests during the process on the operator's

knee, who takes a stone adze about 2 inches long, with which he strikes the glass. The adze is a smooth stone, not a flint. The natives had made, prior to the visits of Europeans, spear heads of flint, which are still manufactured in the back districts of the country, and the glass implements are of the same pattern. Mother-of-pearl shell is sometimes used for making spear heads, but it is apparently ground, and not chipped to the required shape.

2. *The Genesis of Implement-making.* *By* F. H. Cushing.

3. *Adze-making in the Andaman Islands.* *By* Professor A. C. Haddon.

Section I.—PHYSIOLOGY, including Experimental Pathology and Experimental Psychology.

President of the Section—Professor Michael Foster, M.D., Sec. R.S.

THURSDAY, AUGUST 19.

The President delivered the following Address:—

We who have come from the little island on the other side of the great waters to take part in this important gathering of the British Association, have of late been much exercised in retrospection. We have been looking back on the sixty years reign of our beloved Sovereign, and dwelling on what has happened during her gracious rule. We have, perhaps, done little in calling to mind the wrongs, the mistakes and the failures of the Victorian era; but our minds and our mouths have been full of its achievements and its progress; and each of us, of himself or through another, has been busy in bringing back to the present the events of more than half a century of the past. It was while I, with others, was in this retrospective mood that the duty of preparing some few words to say to you to day seemed suddenly to change from an impalpable cloud in the far distance to a heavy burden pressing directly on the back; and in choosing something to say I have succumbed to the dominant influence. Before putting pen to paper, however, I recovered sufficiently to resist the temptation to add one more to the many reviews which have appeared of the progress of physiology during the Victorian era. I also rejected the idea of doing that for which I find precedents in past presidential addresses—namely, of attempting to tell what has been the history of the science to which a Section is devoted during the brief interval which has elapsed since the Section last met; to try and catch physiology, or any other science, as it rushes through the brief period of some twelve months seemed to me not unlike photographing the flying bullet without adequate apparatus; the result could only be either a blurred or a delusive image. But I bethought me that this is not the first, we hope it will not be the last, time that the British Association has met in the Western Hemisphere; and though the events of the thirteen years which have slipped by since the meeting at Montreal in 1884 might seem to furnish a very slender oat on which to pipe a presidential address, I have hoped that I might be led to sound upon it some few notes which might be listened to.

And indeed, though perhaps when we come to look into it closely almost every period would seem to have a value of its own, the past thirteen years do, in a certain sense, mark a break between the physiology of the past and that of the future. When the Association met at Montreal in 1884, Darwin, whose pregnant ideas have swayed physiology in the limited sense of that word, as well as that broader study of living beings which we sometimes call biology, as indeed they have every branch of natural knowledge, had been taken from us only some two years before, and there were still alive most of the men who did the great works of physiology of the middle and latter half of this century. The gifted Claude

Bernard had passed away some years before, but his peers might have been present at Montreal. Bowman, whose classic works on muscle and kidney stand out as peaks in the physiological landscape of the past, models of researches finished and complete so far as the opportunities of the time would allow, fruitful beginnings and admirable guides for the labours of others. Brown-Sequard, who shares with Bernard the glory of having opened up the great modern path of the influence of the nervous system on vascular and thus on nutritional events, and who, if he made some mistakes, did many things which will last for all time. Brücke, whose clear judgment, as shown in his digestive and other work, gave permanent value to whatever he put forth. Du Bois Reymond, who, if he laboured in a narrow path, set a brilliant example of the way in which exact physical analysis may be applied to the phenomena of living beings, and in other ways had a powerful influence on the progress of physiology. Donders, whose mind seemed to have caught something of the better qualities of the physiological organ to which his professional life was devoted, and our knowledge of which he so largely extended, so sharply did he focus his mental eye on every physiological problem to which he turned—and these were many and varied. Helmholtz, whose great works on vision and hearing, to say nothing of his earlier distinctly physiological researches, make us feel that if physics gained much, physiology lost even more when the physiologist turned aside to more distinctly physical inquiries. Lastly, and not least, Ludwig, who by his own hands or through his pupils did so much to make physiology the exact science which it is to-day, but which it was not when he began his work. I say lastly, but I might add the name of one who, though barred by circumstances from contributing much directly to physiology by way of research, so used his powerful influence in many ways in aid of physiological interests as to have helped the science onward to no mean extent, at least among English-speaking people—I mean Huxley. All these might have met at Montreal. They have all left us now. Among the peers of the men I have mentioned whose chief labours were carried on in the forties, the fifties and the sixties of the century, one prominent inquirer alone seems to be left, Albert von Kölliker, who in his old age is doing work of which even he in his youth might have been proud. The thirteen years which have swept the others away seem to mark a gulf between the physiological world of to-day and that of the time in which most of their work was done.

They are gone, but they have left behind their work and their names. May they of the future, as I believe we of the present are doing, take up their work and their example, doing work other than theirs but after their pattern, following in their steps.

In the thirteen years during which these have passed away physiology has not been idle. Indeed, the more we look into the period the more it seems to contain.

The study of physiology, as of other sciences, though it may be stimulated by difficulties (and physiology has the stimulus of a special form of opposition unknown to other sciences), expands under the sunshine of opportunity and aid. And it may be worth while to compare the opportunities for study of physiology in 1884 with those in 1897. At this meeting of the British Association I may fitly confine myself I was going to say to British matters; but I feel at this point, as others have felt, the want of a suitable nomenclature. We who are gathered here to-day have, with the exception of a few honoured guests from the Eastern Hemisphere, one common bond, one common token of unity, and, so far as I know, one only; I am speaking now of outward tokens; down deeper in our nature there are, I trust, yet others. We all speak the English tongue. Some of us belong to what is called Great Britain and Ireland, others to that which is sometimes spoken of as Greater Britain. But there are others here who belong to neither; though English in tongue, they are in no sense British. To myself, to whom the being English in speech is a fact of far deeper moment than any political boundary, and who wish at the present moment to deal with the study of physiology among all those who speak the English tongue, there comes the great want of some word which will denote all such. I hope, indeed I think, that others feel the same want too. The term Anglo-Saxon

is at once pedantic and incorrect, and yet there is none other; and, in the absence of such a better term, I shall be forgiven if I venture at times to use the seemingly narrow word English as really meaning something much broader than British in its very broadest sense.

Using English in this sense, I may, I think, venture to say that the thirteen years which separate 1884 from to-day have witnessed among English people a development of opportunities for physiological study such as no other like period has seen. It is not without significance that only a year or two previous to this period, in England proper, in little England, neither of the ancient Universities of Oxford and Cambridge, which, historically at least, represent the fullest academical aspirations of the nation, possessed a chair of physiology; the present professors, who are the first, were both appointed in 1883. Up to that time the science of physiology had not been deemed worthy, by either university, of a distinctive professorial mechanism. The act of these ancient institutions was only a manifestation of modern impulses, shared also by the metropolis and by the provinces at large. Whereas up to that time the posts for teaching physiology, by whatever name they were called, had been in most cases held by men whose intellectual loins were girded for other purposes than physiology, and who used the posts as stepping-stones for what they considered better things, since that time, as each post became vacant, it has almost invariably been filled by men wishing and purposing at least to devote their whole energies to the science. Scotland, in many respects the forerunner of England in intellectual matters, had not so much need of change; but she, too, has moved in the same direction, as has also the sister island.

And if we turn to this Western Continent, we find in Canada and in the States the same notable enlargement of physiological opportunity, or even a still more notable one. If the English-speaking physiologist dots on the map each place on this Western Hemisphere which is an academic focus of his science, he may well be proud of the opportunities now afforded for the development of English physiology; and the greater part of this has come within the last thirteen years.

Professorial chairs or their analogues are, however, after all but a small part of the provision for the development of physiological science. The heart of physiology is the laboratory. It is this which sends the life-blood through the frame; and in respect to this, perhaps, more than to anything else, has the progress of the past thirteen years been striking. Doubtless, on both sides of the waters there were physiological laboratories, and good ones, in 1884; but how much have even these during that perod been enlarged and improved, and how many new ones have been added? In how many places, even right up to about 1884, the professor or lecturer was fain to be content with mere lecture experiments and a simple course of histology, with perhaps a few chemical exercises for his students! Now each teacher, however modest his post, feels and says that the authorities under whom he works are bound to provide him with the means of leading his students along the only path by which the science can be truly entered upon, that by which each learner repeats for himself the fundamental observations on which the science is based.

But there is a still larger outcome from the professorial chair and the physiological laboratory than the training of the student; these are opportunities not for teaching only, but also for research. And perhaps in no respect has the development during the past thirteen years been so marked as in this. Never so clearly as during this period has it become recognised that each post for teaching is no less a post for learning, that among academic duties the making knowledge is as urgent as the distributing it, and that among professorial qualifications the gift of garnering in new truths is at least as needful as facility in the didactic exposition of old ones. Thirteen years has seen a great change in this matter, and the progress has been perhaps greater on this side of the water than on the other, so far as English-speaking people are concerned. We on the other side have witnessed with envy the establishment on this side of a university, physiology having in it an honoured place, the keynote of which is the development of original research. It will, I venture to think, be considered a strong confirmation of my present theme that the Clark University at Worcester was founded only ten years ago.

And here, as an English-speaking person, may I be allowed to point out, not without pride, that these thirteen years of increased opportunity have been thirteen years of increased fruitfulness. In the history of our science, among the names of the great men who have made epochs, English names, from Harvey onwards, occupy no mean place; but the greatness of such great men is of no national birth; it comes as it lists, and is independent of time and of place. If we turn to the more everyday workers, whose continued labours more slowly build up the growing edifice and provide the needful nourishment for the greatness of which I have just spoken, we may, I will dare to say, affirm that the last thirteen years has brought contributions to physiology, made known in the English tongue, which, whether we regard their quantity or their quality, significantly outdo the like contributions made in any foregoing period of the same length. Those contributions have been equally as numerous, equally as good on this side as on the other side of the waters. And here I trust I shall be pardoned if personal ties and affection lead me to throw in a personal word. May I not say that much which has been done on this side has been directly or indirectly the outcome of the energy and gifts of one whom I may fitly name on an occasion such as this, since, though he belonged to the other side, his physiological life was passed and his work was done on this side, one who has been taken from us since this Association last met, Henry Newell Martin?

Yes, during these thirteen years, if we put aside the loss of comrades, physiology has been prosperous with us and the outlook is bright; but, as every cloud has its silver lining, so shadow follows all sunshine, success brings danger, and something bitter rises up amid the sweet of prosperity. The development of which I have spoken is an outcome of the progressive activity of the age, and the dominant note of that activity is heard in the word 'commercial.' Noblemen and noblewomen open shop, and every one, low as well as high, presses forward towards large or quick profits. The very influences which have made devotion to scientific inquiry a possible means of livelihood, and so fostered scientific investigation, are creating a new danger. The path of the professor was in old times narrow and strait, and only the few who had a real call cared to tread it; nowadays there is some fear lest it become so broad and so easy as to tempt those who are in no way fitted for it. There is an increasing risk of men undertaking a research, not because a question is crying out to them to be answered, but in the hope that the publication of their results may win for them a lucrative post. There is, moreover, an even greater evil ahead. The man who lights on a new scientific method holds the key of a chamber in which much gold may be stored up; and strong is the temptation for him to keep the new knowledge to himself until he has filled his fill, while all the time his brother-inquirers are wandering about in the dark through lack of that which he possesses. Such a selfish withholding of new scientific truth is beginning to be not rare in some branches of knowledge. May it never come near us!

Now I will, with your permission, cease to sound the provincial note, and ask your attention for a few minutes while I attempt to dwell on what seem to me to be some of the salient features of the fruits of physiological activity, not among English-speaking people only, but among all folk, during the past thirteen years.

When we review the records of research and discovery over any lengthened period, we find that in every branch of the study progress is irregular, that it ebbs and flows. At one time a particular problem occupies much attention, the periodicals are full of memoirs about it, and many of the young bloods flesh their maiden swords upon it. Then again for awhile it seems to lie dormant and unheeded. But quite irrespective of this feature, which seems to belong to all lines of inquiry, we may recognise two kinds of progress. On the one hand, in such a period, in spite of the waves just mentioned, a steady advance continually goes on in researches which were begun and pushed forward in former periods, some of them being of very old date. On the other hand, new lines of investigation, starting with quite new ideas or rendered possible by the introduction of new methods, are or may be begun. Such naturally attract great attention, and give a special character to the period.

In the past thirteen years we may recognise both these kinds of progress. Of the former kind I might take, as an example, the time-honoured problems of the mechanics of the circulation. In spite of the labour which has been spent on these in times of old, something always remains to be done, and the last thirteen years have not been idle. The researches of Hürthle and Tigerstedt, of Roy and Adami, not to mention others, have left us wiser than we were before. So again, with the also old problems of muscular contraction, progress, if not exciting, has been real; we are some steps measurably nearer an understanding what is the exact nature of the fundamental changes which bring about contraction and what are the relations of those changes to the structure of muscular fibre. In respect to another old problem, too, the beat of the heart, we have continued to creep nearer and nearer to the full light. Problems again, the method of attacking which is of more recent origin, such as the nature of secretion, and the allied problem of the nature of transudation, have engaged attention and brought about that stirring of the waters of controversy which, whatever be its effects in other departments of life, is never in science wholly a waste of time, if indeed it be a waste of time at all, since, in matters of science, the tribunal to which the combatants of both sides appeal is always sure to give a true judgment in the end. In the controversy thus arisen, the last word has perhaps not yet been said, but whether we tend at present to side with Heidenhain, who has continued into the past thirteen years the brilliant labours which were perhaps the distinguishing features of physiological progress in preceding periods, and who in his present sufferings carries with him, I am sure, the sympathies if not the hopes of all his brethren, or whether we are more inclined to join those who hold different views, we may all agree in saying that we have, in 1897, distinctly clearer ideas of why secretion gathers in an alveolus or lymph in a lymph space than we had in 1884.

I might multiply such examples of progress on more or less old lines until I wearied you; but I will try not to do so. I wish rather to dwell for a few minutes on some of what seem to be the salient new features of the period under review.

One such feature is, I venture to think, the development of what may perhaps be called the new physiological chemistry. We always are, and for a long time always have been, learning something new about the chemical phenomena of living beings. During the years preceding those immediately recent, great progress, for which we have especially, perhaps, to thank Kühne, was made in our knowledge of the bodies which we speak of as proteids and their allies. But while admitting to the full the high value of all these researches, and the great light which they threw on many of the obscurer problems of the chemical changes of the body, such, for instance, as the digestive changes and the clotting of blood, it could not but be felt that their range was restricted and their value limited. Granting the extreme usefulness of being able to distinguish bodies though their solution or precipitation by means of this or that salt or acid, this did not seem to promise to throw much light on the all-important problem as to what was the connection between the chemical constitution of such bodies and their work in the economy of a living being. For it need not be argued that this is an all-important problem. To day, as yesterday and as in the days before, the mention of the word vitalism or its equivalent separates as a war-cry physiologists into two camps, one contending that all the phenomena of life can, and the other that they cannot, be explained as the result of the action of chemico-physical forces. For myself, I have always felt that while such a controversy, like other controversies as I ventured to say just now, is useful as a stirring of the waters, through which much oxygen is brought home to many things and no little purification effected, the time for the final judgment on the question will not come until we shall more clearly understand than we do at present what we mean by physical and chemical, and may perhaps be put off until somewhere near the end of all things, when we shall know as fully as we ever shall what the forces to which we give these names can do and what they cannot. Meanwhile the great thing is to push forward, so far as may be, the chemical analysis of the phenomena presented by living beings. Hitherto the physiological chemists, or the chemical physiologists as perhaps they ought rather to be called have perhaps gone too much their own gait, and have seemed to be

constructing too much a kind of chemistry of their own. But that, may I say, has in part been so because they did not receive from their distinctly chemical brethren the help of which they were in need. May I go so far as to say that to us physiologists these our brethren seemed to be lagging somewhat behind, at least along those lines of their science which directly told on our inquiries? That is, however, no longer the case. They are producing work and giving us ideas which we can carry straight into physiological problems. The remarkable work of Emil Fischer on sugars, one of the bright results of my period of thirteen years, may fully be regarded as opening up a new era in the physiology of the carbohydrates, opening up a new era because it has shown us the way how to investigate physiological problems on purely and distinctively chemical lines. Not in the carbohydrates only, but in all directions our younger investigators are treating the old problems by the new chemical methods; the old physiological chemistry is passing away; nowhere, perhaps, is the outlook more promising than in this direction; and we may at any time receive the news that the stubborn old fortress of the proteids has succumbed to the new attack.

Another marked feature of the period has been the increasing attention given to the study of the lower forms of life, using their simpler structures and more diffuse phenomena to elucidate the more general properties of living matter. During the greater part of the present century physiologists have, as a rule, chosen as subjects of their observations almost exclusively the vertebrata; by far the larger part of the results obtained during this time have been gained by inquiries restricted to some half a dozen kinds of backboned animals; the frog and the myograph, the dog and the kymograph have almost seemed the alpha and the omega of the science. This has been made a reproach by some, but, I cannot help thinking, unjustly. Physiology is, in its broad meaning, the unravelling of the potentialities of things in the condition which we call living. In the higher animals the evolution by differentiation has brought these potentialities, so to speak, near the surface, or even laid them bare as actual properties capable of being grasped. In the lower animals they still lie deep buried in primeval sameness; and we may grope among them in vain unless we have a clue furnished by the study of the higher animal. This truth seems to have been early recognised during the progress of the science. In the old time, observers such as Spallanzani, with but a moderate amount of accumulated knowledge behind them, and a host of problems before them, with but few lines of inquiry as yet definitely laid down, were free to choose the subjects of their investigation where they pleased, and in the wide field open to them prodded so to speak among all living things, indifferent whether they possessed a backbone or no. But it soon became obvious that the study of the special problems of the more highly organised creature was more fruitful, or at least more easily fruitful, than that of the general problems of the simpler forms; and hence it came about that inquiry, as it went on, grew more and more limited to the former. But an increasing knowledge of the laws of life as exemplified in the differentiated phenomena of the mammal is increasingly fitting us for a successful attack on the more general phenomena of the lowly creatures possessing little more than that molecular organisation, if such a phrase be permitted, which alone supplies the conditions for the manifestation of vital activities. And, though it may be true that in all periods men have from time to time laboured at this theme, I think that I am not wrong in saying that the last dozen years or so mark a distinct departure both as regards the number of researches directed to it, and also, what is of greater moment, as regards the definiteness and clearness of the results thereby obtained. One has only to look at the results recorded in the valuable treatises of Verworn and Biedermann, whether obtained by the authors themselves or by others, to feel great hope that in the immediately near future a notable advance will be made in our grasp of the nature of that varying collection of molecular conditions, potencies and changes, slimy hitherto to the intellectual no less than to the physical touch, which we are in the habit of denoting by the more or less magical word protoplasm. And perhaps one happy feature of such an advance will be one step in the way of that reintegration which men of science fondly hope may ultimately follow the differentiation of studies now so fierce and

attended by many ills; in the problems of protoplasm the animal physiologist touches hands with the botanist, and both find that under different names they are striving towards the same end.

Closely allied to and indeed a part of the above line of inquiry is the study of the physiological attributes of the cell and of their connection with its intrinsic organisation. This is a study which, during the last dozen years, has borne no mean fruits; but it is an old study, one which has been worked at from time to time, reviving again and again as new methods offered new opportunities. Moreover, it will probably come directly before us in our sectional work, and therefore I will say nothing more of it here.

Still another striking feature of the past dozen years has been the advance of our knowledge in regard to those events of the animal body which we have now learnt to speak of as 'internal secretion.' This knowledge did not begin in this period. The first note was sounded long ago in the middle of the century, when Claude Bernard made known what he called 'the glycogenic function of the liver.' Men, too, were busy with the thyroid body and the suprarenal capsules long before the meeting of the British Association at Montreal. But it was since then, namely in 1889, that Minkowski published his discovery of the diabetic phenomena resulting from the total removal of the pancreas. That, I venture to think, was of momentous value, not only as a valuable discovery in itself, but especially, perhaps, in confirming and fixing our ideas as to internal secretion, and in encouraging further research.

Minkowski's investigation possessed this notable feature, that it was clear, sharp and decided, and, moreover, the chief factor, namely sugar, was subject to quantitative methods. The results of removing the thyroid body had been to a large extent general, often vague, and in some cases uncertain; so much so as to justify, to a certain extent, the doubts held by some as to the validity of the conclusion that the symptoms witnessed were really and simply due to the absence of the organ removed. The observer who removes the pancreas has to deal with a tangible and measurable result, the appearance of sugar in the urine. About this there can be no mistake, no uncertainty. And the confidence thus engendered in the conclusion that the pancreas, besides secreting the pancreatic juice, effects some notable change in the blood passing through it, spread to the analogous conclusions concerning the thyroid and the suprarenal, and moreover suggested further experimental inquiry. By those inquiries all previous doubts have been removed; it is not now a question whether or no the thyroid carries on a so-called internal secretion; the problem is reduced to finding out what it exactly does and how exactly it does it. Moreover, no one can at the present day suppose that this feature of internal secretion is confined to the thyroid, the suprarenal, and the pancreas; it needs no spirit of prophecy to foretell that the coming years will add to physiological science a large and long chapter, the first marked distinctive verses of which belong to the dozen years which have just passed away.

The above three lines of advance are of themselves enough to justify a certain pride on the part of the physiologist as to the share which his science is taking in the forward movements of the time. And yet I venture to think that each and all of these is wholly overshadowed by researches of another kind, through which knowledge has made, during the past dozen years or so, a bound so momentous and so far-reaching that all other results gathered in during the time seem to shrink into relative insignificance.

It was a little before my period, in the year 1879, that Golgi published his modest note, 'Un nuovo processo di technica microscopica.'[1] That was the breaking out from the rocks of a little stream which has since swollen into a great flood. It is quite true that long before a new era in our knowledge of the central nervous system had been opened up by the works of Ferrier and of Fritsch and Hitzig. Between 1870 and 1880 progress in this branch of physiology had been continued and rapid. Yet that progress had left much to be desired. On the one hand the experimental

[1] *Rendiconti del reale Istituto Lombardo*, vol. xii. p. 206. My friend Professor Minot has called my attention to the fact that Golgi really published his method before this, viz., in his 'Ricerche sulla fina struttura dei bulbi olfattorii,' 1875.

inquiries, even when they were carried out with the safeguard of an adequate psychical analysis of the phenomena which presented themselves, and this was not always the case, sounded a very uncertain note, at least when they dealt with other than simply motor effects. They were, moreover, not unfrequently in discord with clinical experience. In general the conclusions which were arrived at through them, save such as were based on the production of easily recognised and often measurable movements, were regarded by many as conclusions of the kind which could not be ignored, which demanded respectful attention, and yet which failed to carry conviction. It seemed to be risking too much to trust too implicitly to the apparent teaching of the results arrived at; something appeared wanting to give these their full validity, to explain their full and certain meaning by showing their connection with what was known in other ways and by other methods. On the other hand, during nearly all this time, in spite of the valuable results acquired by the continually improving histological technique, by the degeneration method, and by the developmental method, by the study of the periods of myelination, most of us, at all events, were sitting down, as our forefathers had done, before the intricate maze of encephalic structure, fascinated by its complexity, but wondering what it all meant. Even when we attempted to thread our way through the relatively simple tangle of the spinal cord, to expect that we should ever see our way so to unravel out the strands of fibres, here thick, there thin, now twisting and turning, and anon running straight, or so to set out in definite constellations the seeming milky way of star-like cells, so to do this as to make the conformation of the cord explain the performances of which it is capable, appeared to be something beyond our reach. And when we passed from the cord to those cerebral structures the even gross topography of which is the despair of the beginner in anatomical studies, the multiple maze of grey and white matter seemed to frame itself into the letters graven on the gateway of the city of Dis, and bid us leave all hope behind.

What a change has come upon us during the past dozen years, and how great is the hope of ultimate success which we have to-day. Into what at the meeting at Montreal seemed a cloudy mass, in which most things were indistinct and doubtful, and into which each man could read images of possible mechanisms according as his fancy led, the method of Golgi has fallen like a clarifying drop, and at the present moment we are watching with interest and delight how that vague cloud is beginning to clear up and develop into a sharp and definite picture, in which lines objectively distinct and saying one thing only reveal themselves more and more. This is not the place to enter into details, and I will content myself with pointing out as illustrative of my theme the progress which is being made in our knowledge of how we hear and how sounds affect us. A dozen years ago we possessed experimental and clinical evidence which led us to believe that auditory impulses sweeping up the auditory nerve became developed into auditory sensations through events taking place in the temporo-sphenoidal convolution, and we had some indications that as these passed upward through the lower and middle brain the striæ acusticæ and the lateral fillet had some part to play. Beyond this we knew but little. To-day we can with confidence construct a diagram which he who runs can read, showing how the impulses undergoing a relay in the tuberculum acusticum and accessory nucleus pass by the striæ acusticæ and trapezoid fibres to the superior olive and trapezoid nucleus, and onwards by the lateral fillet to the posterior corpus quadrageminum and to the cortex of the temporo-sphenoidal convolution. And if much, very much, yet remains to be done even in tracking out yet more exactly the path pursued by the impulses while they are still undeveloped impulses, not as yet lit up with consciousness, and in understanding the functional meaning of relays and apparently alternate routes, to say nothing of the deeper problems of when and how the psychical element intervenes, we feel that we have in our hands the clue by means of which we may hope to trace out clearly the mechanisms by which, whether consciousness plays its part or no, sounds affect so profoundly and so diversely the movements of the body, and haply some time or other to tell, in a plain and exact way, the story of how we hear. I have thus referred to hearing because the problems connected with this seemed, thirteen years ago, so eminently obscure; it appeared so pre-eminently

hard a task, that of tracing out the path of an auditory impulse through the confused maze of fibre and cell presented by the lower and middle brain. Of the mechanism of sight we seemed even then to have better knowledge, but how much more clearly do we, so to speak, see vision now? So also with all other sensations, even those most obscure ones of touch and pain; indeed, all over the nervous system light seems breaking in a most remarkable way.

This great and significant progress we owe, I venture to say, to Golgi, to the method introduced by him; and I for one cannot help being glad that this important contribution to science, as well as another contingent and most valuable one, the degeneration method of Marchi, should be among the many tokens that Italy, the mother of all sciences in times gone by, is now once more taking her right place in scientific no less than in political life. We owe, I say, this progress to Golgi in the sense that the method introduced by him was the beginning of the new researches. We owe, moreover, to Golgi not the mere technical introduction of the method, but something more. He himself pointed out the theoretical significance of the results which his method produced; and if in this he has been outstripped and even corrected by others, his original merit must not be allowed to be forgotten. Those others are many, in many lands. Among the first was one Frithiof Nansen, whose brilliant though brief memoir makes us selfish physiologists regret that the icy charms of the North Pole so early froze in him the bubbling spring of histological research. From the rest two names stand out conspicuous. If rejuvenescent Italy invented the method, another ancient country, whose fame, once brilliant in the past, like that of Italy, suffered in later times an eclipse, produced the man who, above all others, has showed us how to use it. At the meeting at Montreal a voice from Spain telling of things physiological would have seemed a voice crying out of the wilderness; to-day the name of Ramon-y-Cayal is in every physiologist's mouth. That is one name, but there is yet another. Years ago, when those of us who are now veterans and see signs that it is time for us to stand aside were spelling out the primer of histology, one name was always before us as that of a man who touched every tissue and touched each well. It is a consoling thought to some of us elder ones that histological research seems to be an antidote to senile decay. As the companion of the young Spaniard in the pregnant work on the histology of the central nervous system done in the eighties and the nineties of the century, must be named the name of the man who was brilliant in the fifties, Albert von Kölliker.

When I say that the progress of our knowledge of the central nervous system during the past thirteen years has been largely due to the application of the method of Golgi, I do not mean that it, alone and by itself, has done what has been done. That is not the way of science. Almost every thrust forward in science is a resultant of concurrent forces working along different lines; and in most cases at least significant progress comes when efforts from different quarters meet and join hands. And especially as regards methods it is true that their value and effect depend on their coming at their allotted times. As I said above, neither experimental investigation nor clinical observation nor histological inquiry by the then known methods, had been idle before 1880. They had moreover borne even notable fruits, but one thing was lacking for their fuller fruition. The experimental and clinical results all postulated the existence of clear definite paths for impulses within the central nervous system, of paths moreover which, while clear and sharp, were manifold and, under certain conditions, alternate or even vicarious, and were so constructed that the impulses as they swept along them underwent from time to time—that is, at some place or other—transformations or at least changes in nature. But the methods of histological investigations available before that of Golgi, though they taught us much, failed to furnish such an analysis of the tangle of grey and white matter as would clearly indicate the paths required. This the method of Golgi did, or rather is doing. Where gold failed silver has succeeded, and is succeeding. Thanks to the black tract which silver when handled in a certain way leaves behind it in the animal body, as indeed it does elsewhere, we can now trace out, within the central nervous system, the pathway afforded by the nerve cell and the nerve cell alone. We see its dendrites branching out in various

directions, each alert to dance the molecular dance assigned to it at once by the more lasting conditions which we call structural, and the more passing ones which we call functional, so soon as some partner touch its hand. We see the body of the cell with its dominant nucleus ready to obey and yet to marshal and command the figure so started. We see the neuraxon prepared to carry that figure along itself, it may be to far-distant parts, it may be to near ones, or to divert it along collaterals, it may be many, or it may be few, or to spread out at once among numerous seemingly equipollent branches. And whether it prove ultimately true or no that the figure of the dancing molecules sweeps always onwards along the dendrites towards the nucleus, and always outwards away from the nucleus along the neuraxon, or whatever way in the end be shown to be the exact differences in nature and action between the dendrites and the neuraxon, this at least seems sure, that cell plays upon cell only by such a kind of contact as seems to afford an opportunity for change in the figure of the dance, that is to say, in the nature of the impulse, and that in at least the ordinary play it is the terminal of the neuraxon (either of the main core or a collateral) of one cell which touches with a vibrating touch the dendrite or the body of some other cell. We can thus, I say, by the almost magic use of a silver token—I say magic use, for he who for the first time is shown a Golgi preparation is amazed to learn that it is such a sprawling thing as he sees before him which teaches so much, and yet when he comes to use it acquires daily increased confidence in its worth—it is by the use of such a silver token that we have been able to unravel so much of the intricate tangle of the possible paths of nervous impulses. By themselves, the acquisition of a set of pictures of such black lines would be of little value. But, and this I venture to think is the important point, to a most remarkable extent, and with noteworthy rapidity, the histological results thus arrived at, aided by analogous results reached by the degeneration method, especially by the newer method akin to that of Golgi, that of Marchi, have confirmed or at times extended and corrected the teachings of experimental investigation and clinical observation. It is this which gives strength to our present position; we are attacking our problems along two independent lines. On the one hand we are tracing out anatomical paths, and laying bare the joints of histological machinery; on the other hand, beginning with the phenomena, and analysing the manifestations of disorder, whether of our own making or no, as well as of order, we are striving to delineate the machinery by help of its action. When the results of the two methods coincide, we may be confident that we are on the road of all truth; when they disagree, the very disagreement serves as the starting-point for fresh inquiries along the one line or the other.

Fruitful as have been the labours of the past dozen years, we may rightly consider them as but the earnest of that which is to come; and those of us who are far down on the slope of life may wistfully look forward to the next meeting of the Association on these Western shores, wondering what marvels will then be told.

Physiology, even in the narrower sense to which, by emphasis on the wavering barrier which parts the animal from the plant, it is restricted in this Section, deals with many kinds of being, and with many things in each. But, somewhat as man, in one aspect a tiny fragment of the world, still more of the universe, in another aspect looms so great as to overshadow everything else, so the nervous system, seen from one point of view, is no more than a mere part of the whole organism, but, seen from another point of view, seems by its importance to swallow up all the rest. As man is apt to look upon all other things as mainly subserving his interests and purposes, so the physiologist, but with more justice, may regard all the rest of the body as mainly subserving the welfare of the nervous system; and, as man was created last, so our natural knowledge of the working of that nervous system has been the latest in its growth. But, if there be any truth in what I have urged to-day, we are witnessing a growth which promises to be as rapid as it has seemed to be delayed. Little spirit of prophecy is needed to foretell that in the not so distant future the teacher of physiology will hurry over the themes on which he now dwells so long, in order that he may have time to expound the most important of all the truths which he has to tell, those which have to do with the manifold workings of the brain.

And I will be here so bold as to dare to point out that this development of his science must, in the times to come, influence the attitude of the physiologist towards the world, and ought to influence the attitude of the world towards him. I imagine that if a plebiscite, limited even to instructed, I might almost say scientific, men, were taken at the present moment, it would be found that the most prevalent conception of physiology is that it is a something which is in some way an appendage to the art of medicine. That physiology is, and always must be, the basis of the science of healing, is so much a truism that I would not venture to repeat it here were it not that some of those enemies, alike to science and humanity, who are at times called anti-vivisectionists, and whose zeal often outruns, not only discretion, but even truth, have quite recently asserted that I think otherwise. Should such a hallucination ever threaten to possess me, I should only have to turn to the little we yet know of the physiology of the nervous system and remind myself how great a help the results of pure physiological curiosity—I repeat the words, pure physiological curiosity, for curiosity is the mother of science—have been, alike to the surgeon and the physician, in the treatment of those in some way most afflicting maladies, the diseases of the nervous system. No, physiology is, and always must be, the basis of the science of healing; but it is something more. When physiology is dealing with those parts of the body which we call muscular, vascular, glandular tissues and the like, rightly handled she points out the way not only to mend that which is hurt, to repair the damages of bad usage and disease, but so to train the growing tissues and to guide the grown ones as that the best use may be made of them for the purposes of life. She not only heals, she governs and educates. Nor does she do otherwise when she comes to deal with the nervous tissues. Nay, it is the very prerogative of these nervous tissues that their life is above that of all the other tissues, contingent on the environment and susceptible of education. If increasing knowledge gives us increasing power so to mould a muscular fibre that it shall play to the best the part which it has to play in life, the little knowledge we at present possess gives us at least much confidence in a coming far greater power over the nerve cell. This is not the place to plunge into the deep waters of the relation which the body bears to the mind; but this at least stares us in the face, that changes in what we call the body bring about changes in what we call the mind. When we alter the one, we alter the other. If, as the whole past history of our science leads us to expect, in the coming years a clearer and deeper insight into the nature and conditions of that molecular dance which is to us the material token of nervous action, and a fuller, exacter knowledge of the laws which govern the sweep of nervous impulses along fibre and cell, give us wider and directer command over the moulding of the growing nervous mechanism and the maintenance and regulation of the grown one, then assuredly physiology will take its place as a judge of appeal in questions not only of the body, but of the mind; it will raise its voice not in the hospital and consulting-room only, but also in the senate and the school.

One word more. We physiologists are sorely tempted towards self-righteousness, for we enjoy that blessedness which comes when men revile you and persecute you and say all manner of evil against you falsely. In the mother-country our hands are tied by an Act which was defined by one of the highest legal authorities as a 'penal' Act; and though with us, as with others, difficulties may have awakened activity, our science suffers from the action of the State. And some there are who would go still farther than the State has gone, though that is far, who would take from us even that which we have, and bid us make bricks wholly without straw. To go back is always a hard thing, and we in England can hardly look to any great betterment for at least many years to come. But unless what I have ventured to put before you to-day be a mocking phantasm, unworthy of this great Association and this great occasion, England in this respect at least offers an example to be shunned alike by her offspring and her fellows.

The following Papers were read :—

1. *The Rhythm of Smooth Muscles.* *By* Professor H. P. BOWDITCH.

Gaskell ('Journal of Physics,' iv. 118) has called attention to the fact that the three sorts of muscle fibre recognised by physiologists—namely, striped, smooth and cardiac fibres—are each characterised by the special development of a particular form of activity, but that each kind of muscle possesses to a certain degree the forms of activity which specially characterise the other kinds. Thus the power of rapid contraction, which is most highly developed in striped muscles to serve the purpose of locomotion, is possessed in a lesser degree by the cardiac, and in a still less degree by the smooth muscles, whereas the power of tonic contraction, strikingly manifested by smooth muscles, is much less marked in the cardiac and striped muscles, and rhythmical contraction, which is the special function of the cardiac muscle, is a phenomenon of subordinate importance in the smooth and striped muscles. The following table represents the order in which the three sorts of muscles stand with regard to the manifestation of the three forms of activity.

—	Rapidity	Tonicity	Rhythm
1.	Striped	Smooth	Cardiac
2.	Cardiac	Cardiac	Smooth
3.	Smooth	Striped	Striped

It is evident, therefore, that the phenomenon of muscular contraction may be conveniently studied under the nine headings indicated in the table, and in this communication the author desired to call attention to a few observations which he has made under one of these headings—viz., that of the rhythmical contraction of smooth muscle fibres. Many of the observations which are here referred to were made ten years ago by R. W. Lovett, but have remained unpublished because the complicated nature of the phenomenon rendered positive conclusions difficult to draw. The material used was a set of three rings of muscular tissue, one or more mm. in width, taken from the cardiac, the middle, and the pyloric portion of the stomach of the frog by sections perpendicular to the axis of the organ. These rings were attached to the recording apparatus by metal hooks, which served at the same time as electrodes, though in the experiments to be reported no electrical stimulation was used.[1]

The curves were traced upward on the smoked surface of a cylinder which could be adjusted to revolve once in a hour, or once in twelve hours. The method of procedure was in general to take the tracing during an hour with the more rapid movement of the drum, and then to shift the cylinder on to the slower movement.

The results of Dr. Lovett's observations may be summarised as follows :—

1. About 50 per cent. of the preparations manifested spontaneous activity as soon as they were attached to the apparatus.
2. In about 13 per cent. of the observations the beginning of the activity occurred after a period of 20 secs. to 3 hours.
3. In 7 per cent. of the cases the delay was more than 3 hours.
4. Thirty per cent. of the preparations remained inactive.
5. Cases of delayed activity and of total inactivity were more frequent in the middle and pyloric than in the cardiac portion of the stomach.

[1] This method is the same as that employed by Morgen (*Untersuchungen, a.d. Phys. Inst. Univ. Halle Heft*, ii. p. 139, 1890) in studying the irritability of smooth muscles. It is to be noted, however, that in Morgen's experiments spontaneous movements of the stomach ceased after about twenty minutes, while in Dr. Lovett's experiments they lasted many hours.

6. The duration of the activity varied from 45 secs. to 24 hours. The average duration was—

For the cardiac portion	. . . . .	$10\frac{1}{2}$ hours.
„ middle „	. . . . .	$10\frac{1}{2}$ „
„ pyloric „	. . . . .	$7\frac{1}{4}$ „

7. The contractions of the middle and pyloric portions were, as a rule, more simple and regular than those of the pyloric portion of the stomach. See also Ducceschi ('Ar. It., de Biol.' xxvii. 61), Experiments on dog's stomach.

Quite recently (March, 1897), the apparatus being brought into use in a class demonstration, the tracings of one of the pieces of stomach was observed to present an appearance which suggested the idea that the curve was a compound one formed by the superposition of two sets of rhythmical contractions differing from each other slightly in rate. Diagrams were shown which illustrate two cases of this phenomenon, in one of which there was a difference of 5 and in the other a difference of 17 seconds in the rate of the constituent rhythms.

Another form of rhythm occasionally presented by smooth muscles studied in this way is the repetition of a complicated set of contractions, the separate contractions of each set differing from each other in appearance, but the set as a whole being a repetition of the previous set.

It is evident that if two or more such complicated sets of contraction occur simultaneously in the same preparation, the resulting curve will be of a nature to almost defy analysis.

A few experiments directed to the determination of the influence of hunger and digestion upon the nature of the gastric movements led to no definite result.

Neither was any connection to be observed between the width of the muscular ring and the complication of the curve.

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2. *The Innervation of Motor Tissues, with especial reference to Nerve-endings in the Sensory Muscle-spindles.* *By* Professor G. CARL HUBER, *M.D.*, and Mrs. DE WITT.

The observations here recorded were made with the methylen-blue method, as modified by Bethe. A 1 per cent. solution of methylen-blue was injected into the blood-vessels; the tissues to be studied were fixed in ammonium molybdate, sectioned, and double-stained in alum carmine.

The results obtained were as follows:—

Nerve-ending in Striated Muscle (rabbit and frog). The neuraxis of the motor neurons terminates, under the sarcolemma, in an end-brush, the fibrils of which present the same structure as the neuraxis itself. The so-called 'sole' is an accumulation of *sarcoplasma,* at the place of ending of the motor nerve-fibre, which is continuous with the sarcoplasma of the muscle-fibre. The 'sole nuclei' are muscle-nuclei.

Nerve-ending in Heart-muscle (cat). Heart-muscle receives its innervation from sympathetic nerve-cells. The neuraxes of such nerve-cells terminate in varicose fibrils which end *on* the heart muscle-cell in small bulbar enlargements or in small clusters of such bulbar enlargements.

Nerve-ending in Involuntary Smooth Muscles (intestine of cat, frog, and tortoise). Involuntary smooth muscle receives its nerve-supply from sympathetic nerve-cells. The neuraxes of the sympathetic neurons innervating involuntary muscle end, after repeated branching, in small knobs which rest on the spindle-shaped muscle cells, often near the nucleus.

Nerve-ending in Muscle-spindle. Muscle-spindles were described by Kölliker (under the name 'Muskel-Knospen') in frog's muscle as early as 1862. They were soon after found by Kühne in the voluntary muscles of other vertebrates. Since that time they have been repeatedly described and variously interpreted. They were described as growth-centres by Kölliker, Bremer, Felix, v. Franqué,

Trinchese, Thanhoffer, and Volkmann; as pathological structures by Fränkel, Eisenlohr, Millbacher, Eichhorst, Babinski, and Meyer; as physiological structures, without however assigning any special function to them, by Mays, Roth, Blocq and Marinesco, Pilliet, Christomanson and Strössner; and finally, as sensorial nerve-endings, by Kerschner, Ruffini, Sherrington, and Sihler: Sherrington having shown conclusively by the degeneration-method that the spindle-nerves are spinal root-ganglion nerves.

We were concerned more particularly with the ending of the spindle-nerves in the muscle-spindles; our observations were as follows:—

In the *frog* the spindle-nerves terminate in fine, varicose fibrils, which run along, outside of the sarcolemma, on the intrafusal fibres.

In the *snake* only one intrafusal muscle-fibre is found in the muscle-spindles. The spindle-nerve enters the spindle from the pole, and breaks up into several nonmedullated branches, which follow along by the side of the intrafusal fibres, giving off in their course flat, band-like off-shoots, which partly or completely encircle the intrafusal fibre.

In the *tortoise* the spindle-nerves end in nonmedullated branches, which flatten out into irregular, notched endings having a serpentine course on the intrafusal fibres.

In the *bird* the spindle-nerves terminate in nonmedullated fibres, which have the appearance of a repeatedly folded ribbon.

In *mammalia* the spindle-nerves terminate in ribbon-like endings, which are often distinctly wound around the intrafusal fibre (dog, cat and rat) in the form of a spiral—annulo-spiral endings; or may branch and have a zigzag course on the intrafusal fibre, in which case few spirals are seen (rabbit and probably also man). The ribbon-like nonmedullated fibres terminate by branching and ending in disc-like expansion—flower-like endings of Ruffini.

Some few observations are at hand which go to show that the intrafusal fibres have a motorial ending. In this respect we corroborate Kerschner.

We have regarded the muscle-spindles as sensorial end-organs.

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3. *The Muscle-spindles in Pathological Conditions.* *By* O. F. F. Grünbaum.

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4. *The Ear and the Lateral Line in Fishes.*[1] *By* Frederic S. Lee, *Ph.D.*

The chief morphological facts upon which the theory of the origin of the ear from the system of the lateral line is based are similarity in structure of the adult organs, in innervation, and in ontogeny. Physiology seems able to present at least circumstantial evidence in favour of this theory. The author has investigated the functions of the ear and the sense-organs of the lateral line in fishes.

1. *The Ear.*—The results may be tabulated as follows:—

Functions of the Ear		Sense-organs
I. Dynamical functions in recognition of . .	1. Rotary movements.	Cristæ acusticæ.
	2. Progressive movements.	Maculæ acusticæ.
II. Statical functions in recognition of . .	3. Position in space.	Maculæ acusticæ.

The above functions are divisions of the general function of equilibration: the sense-organs of the ear deal with the equilibrium of the body under all circumstances, both in movement and at rest.

In vertebrates above the fishes we must add to the above:

III. Auditory functions in recognition of . .	4. Vibratory motions.	Papilla acustica basilaris.

Experiments by the author and by Kreidl prove that fishes do not possess the power of audition. Hence the ear in fishes is purely equilibrative in function.

[1] Published in the *Am. Journ. of Physiology*, Jan. 1898.

2. *The Lateral Line.*—Simple cutting of the lateral nerve or destruction of the lateral organs does not seem to affect equilibrium. But destruction of the organs, combined with removal of the pectoral and pelvic fins, causes marked lack of equilibrium, manifested by uncertain, ill-regulated movements; removal of fins alone has no pronounced effect. Central stimulation of the lateral nerve causes the same compensating movements of the fins as does stimulation of the acoustic of the opposite side. These results make it probable that the organs of the lateral line are equilibrative in function, and are employed in the recognition of currents in the water and of movements of the body through the water. The results of Bonnier and of Fuchs are in harmony with this.

This was probably the primitive function. By the inclosure within the skull of a bit of the lateral line and the differentiation and refinement of its sense-organs, a more perfect organ of appreciation of movement, and hence of equilibrium, was evolved in the ear. Along with the appearance of land animals a portion of this organ became still more differentiated and refined and, as the *papilla acustica basilaris*, acquired the power of appreciating the movements that we call sound. Thus equilibration and audition became associated in the same organ.

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5. *On the Effect of Frequency of Excitations on the Contractility of Muscle. By* Professor W. P. LOMBARD.

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6. *A Dynamometric Study of the Strength of the Several Groups of Muscles, and the Relation of Corresponding Homologous Groups of Muscles in Man. By* J. H. KELLOGG, *M.D.*

In the Paper the author describes a new dynamometer so constructed that it may be conveniently employed in testing the strength of each of the important groups of muscles in the body. By means of this apparatus charts have been prepared whereby the strength of each muscular group in the individual may be compared with the strength of those of the average man or the average woman, or the average man or woman of the same height.

By a study of the tabulated results of several thousand examinations the author has been able to formulate a series of new physical coefficients, the chief of which are the following:—

1. The strength-weight coefficient is obtained by dividing the total strength in kilograms by the weight in kilograms, the result showing the number of kilograms which a person is able to lift for each kilogram of his own weight. This coefficient expresses the dynamic value or capacity of a person's body.

2. The respiratory-weight coefficient, obtained by multiplying the lung capacity in litres as shown by the spirometer, by the respiratory strength in kilograms, and dividing the result by the body weight in kilograms. This coefficient expresses the respiratory capacity for each kilogram.

3. The strength-height coefficient, obtained by dividing the total strength in kilograms by the total height in millimetres. This coefficient expresses the number of kilograms which an individual is able to lift for each millimetre in height.

4. The respiratory-height coefficient, obtained by multiplying the lung capacity in litres by the respiratory strength in kilograms and dividing by the height in millimetres. This coefficient represents the respiratory capacity of the individual for each millimetre in height.

5. The coefficient of vital efficiency, obtained by dividing the respiratory-weight coefficient by the strength-weight coefficient. This coefficient combines in one expression the relations represented by the respiratory-weight and the strength-weight coefficients, and represents the relation of a person's respiratory capacity to his working capacity.

6. The coefficient of vital development, obtained by dividing the respiratory-height by the strength-height coefficient, which combines in one expression the

relations represented by the respiratory-height and the strength-height coefficient respectively, and indicates at once whether a person's respiratory development is properly proportioned to his motor development.

The same data from which these several coefficients are deduced afford opportunity for the formulation of a coefficient relating to any individual group of muscles.

The extended study of the strength of various muscular groups by comparison with each other and with the strength of the body as a whole, or of distinct sections of the body, has developed numerous interesting relations. In this comparative study chief attention has been given to the following points:—

1. The relative strength of each group of the muscles, and of each division of the body, and also of the total muscular strength, as compared with the average weight of the body.
2. The strength of each group of muscles, of the muscles of each of the principal divisions of the body, and of the total strength of the body compared with the average height in inches.
3. The strength of each group of muscles, and of the muscles of each of the principal divisions of the body, as compared with the total strength.
4. The strength of each group of muscles (right and left together) as compared with the strength of the corresponding division of the body.
5. The strength of the muscles of the left side of the body as compared with those of the right side of the body.
6. The strength of each group of muscles, of the muscles of each division of the body, and the total strength in women as compared with the same in men.
7. The strength of each group of muscles as compared with the antagonising group.
8. The strength of the muscles of the arms as compared with the homologous or corresponding muscles of the legs.
9. A study of the muscular strength of men as compared with that of women of the same height.
10. A study of the muscular strength in short men and short women as compared respectively with that of tall men and tall women.

FRIDAY, AUGUST 20.

The following Papers and Report were read:—

1. *The Output of the Mammalian Heart. By* Dr. G. N. Stewart.

We possess at present very few data for the determination of the amount of blood thrown out by the left ventricle at each beat. The direct estimation of this important physiological quantity by the introduction of a 'Stromuhr' in the undivided aorta (according to the method of Tigerstedt, in the rabbit), or by the insertion of a measuring cylinder in the course of the lesser circulation, after the great systemic vessels have been tied (as Stolnikow has done in the dog), is not only beset with experimental difficulties, but the results obtained under conditions so highly artificial can hardly be applied with any confidence to the problems of the normal and unobstructed blood-flow. The author of this paper has, accordingly, re-examined the question by means of a new method, and by its aid has measured the output of the heart in a series of dogs, more than twenty in number, and ranging in weight from 5 to nearly 35 kilograms.

Method.—A solution of a substance which can be easily recognised and quantitatively estimated in the blood (1·5 or 2 per cent. sodium chloride) is allowed to flow for a measured time, not greater than the circulation time (usually 10–15 sec.) into the heart. The solution is delivered from a burette connected either with a catheter passed through the jugular vein down nearly to the right auricle (or into

the auricle), or with a glass tube inserted through the carotid artery into the left ventricle. In the latter case, a valve in the course of the connecting tube prevents any back-flow of blood. Both femoral arteries (or sometimes both brachials) are exposed. A cannula (collecting cannula) is inserted into a branch of one of the arteries and the other is laid on two hook-shaped platinum electrodes connected with the Wheatstone's bridge, with which a telephone is connected in the usual way. Weak induction shocks from the secondary of a du Bois coil are sent through the arrangement, including the piece of artery on the electrodes, and the bridge is balanced. When the mixture of blood and salt solution reaches the electrodes the balance is upset, and the telephone announces the moment of arrival of the mixture. A sample of blood is now drawn off by means of the collecting cannula, during the passage of the salt solution, and immediately defibrinated. Then it can be determined at leisure how much of the salt solution must be added to a sample collected before the injection to make its resistance equal to that of the sample collected during the passage of the mixture. Numerous observations can be made in this way on one animal; and from these data the output of the heart for the period of injection, and, therefore, the pulse-rate being known, for a single beat, can be calculated.

Specimens of Results.—In a dog weighing 32·26 kilo. the average output (for the first six observations) was 56·8 c.c. per beat, equal to 2·71 c.c. per kilo. of body-weight per second, with an average pulse-rate of 1·54 per second. In a dog of body-weight 6·48 kilo., the average output was 14·8 c.c. per beat, or 3·52 c.c. per kilo. per second for an average pulse-rate of 1·61. In an animal of intermediate size (18·2 kilo.) the average output for the first five observations was 41·6 c.c. per beat, or 2·31 c.c. per kilo. per second for an average pulse-rate of 1·01.

In general it may be said that the results of these experiments go to show that the more recent measurements of Tigerstedt and Stolnikow are too low, while the older numbers of Volkmann and Vierordt are too high.

The animals were all completely anæsthetised with morphia and ether, or ACE mixture, and were killed before recovering from the anæsthetic.

[Published in full in *Journ. of Physiology*, 1897, v. xxii., p. 159].

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2. *Observations on the Mammalian Heart.* *By* W. T. PORTER.

Experimental evidence was offered in support of the following propositions:—

A. On the cause of the heart-beat.

1. The cause of the rhythmic contraction of the ventricle lies within the ventricle itself.

2. The cause of the rhythmic contraction is not a single, localised co-ordination centre; the co-ordination mechanism, whatever it may be, is present in all parts of the ventricle.

3. The integrity of the whole ventricle is not essential to the co-ordinated contraction of a part of the ventricle.

4. The apex of the mammalian heart possesses spontaneous rhythmic contractility.

5. Assuming that the general belief in the absence of nerve-cells from the apical part of the ventricle is correct, these experiments demonstrate that nerve-cells are not essential to spontaneous, long-continued, co-ordinated contractions of the ventricle.

B. Fibrillary contractions do not destroy beyond recall the power of normal rhythmic, co-ordinated contraction of the heart muscle.

C. The influence of ventricular systole on the blood-flow through the heart muscle.

1. The contraction of the heart compresses the blood-vessels in the substance of the heart.

2. The systole aids the circulation of the blood through the heart muscle.

3. The ventricle acts on the coronary circulation as a force-pump, and not, to any noticeable extent, as a suction-pump.

D. The circulation through the veins of Thebesius.

1. The nutrition of the mammalian heart may be maintained through the vessels of Thebesius in a degree sufficient to give long-continued rhythmic contractions while the coronary arteries are empty.

2. The circulation through the veins of Thebesius is probably an important source of nutrition in hearts in which the coronary arteries have been obstructed by pathological processes.

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3. *On the Resistance of the Vascular Channels. By* Professor K. HÜRTHLE.

For every scientific investigation of the flow of fluid through a tube or system of tubes a knowledge of the three following factors is necessary:—

(1) The pressure at the inlet and outlet of the tube (difference $= b$).
(2) The velocity of flow, or the quantity of fluid flowing through in an unit of time $=$ Q.
(3) The resistance offered to the flow.

Concerning the first two factors in the movement of the blood we have data sufficient for most purposes, but of the third we have no clear conception, since we possess no standard of resistance of the vascular channels.

The amount of this resistance depends on two factors:—

(1) The internal friction of the blood.
(2) The dimensions of the tubular system.

These two factors must therefore first be determined.

1. The method used to determine the internal friction of living blood consists in allowing the blood from (*e.g.*) the carotid of an animal to flow through accurately calibrated capillary tubes for about thirty seconds, the quantity, the pressure and the time of flow being accurately measured, the last to within $\frac{1}{100}$ second.

It was proved that this method, in spite of the short period of observation, gives reliable results by determining with it the internal friction of distilled water. The value obtained was the same as that by Poiseuille.

In the same series of experiments it was also shown that the internal friction can be ascertained even when the pressure varies rhythmically, the outflow being always proportional to the mean pressure, whether the pressure be constant or variable.

The measurements of the *internal friction of the blood* of different animals by this method gave the following results. The ratio of the internal friction of distilled water at 37° C. ($k = 4700$) to that of the blood is—

In the dog $= 1 : 4{\cdot}5$ (K $=$ 1,045).
In the cat $= 1 : 4{\cdot}1$ (K $=$ 1,140).
In the rabbit $= 1 : 3{\cdot}2$ (K $=$ 1,475).

2. Direct determination of the *external resistance* by measurement of the dimension of the system of tubes is impossible, since the variation in tonus causes considerable differences in the calibre of the blood-vessels. But if in any particular organ we know (1) the quantity of blood flowing through in an unit of time ($=$ Q), (2) the arterial pressure ($= b$), (3) the coefficient of internal friction of the blood ($= k$),

$$Q = k\frac{d\,4\,b}{l},$$ where d is the diameter, and l the length of the tube,

we can, by Poiseuille's law, calculate the dimensions of a tube through which, under the given conditions, the same quantity of blood would flow. Such a tube

would represent a numerically expressible resistance. On this basis the following calculations of resistances were made, using R. Tigerstedt's measurements of velocity:—

Vascular channel	Arterial blood pressure (in mm. Hg.)	Vol. of blood flowing through per sec. (cub. mm.)	Coeff. of internal friction	Resistance expressed as tube of (1) diameter in mm.	(2) length in m.
Dog's kidney weighing 100 gr. normal	75	1000	1045	4·6 (diam. of renal artery)	35 m.
The same after injection of diuretics	77	1617	1045	4·6	22 m.
Aortic area of rabbit weighing 1,500 grm.	98	2000	1475	8 (diam. of aorta)	300 m.

By this means the author proposes to measure the resistance through the several organs and the entire vascular course. In this manner an idea can be obtained not only of the amount of resistance in the various vascular paths, but probably also several data for explaining the diameter of the blood-vessels, and the thickness of their walls. For instance, for reasons into which it is not necessary to enter here, it must not be concluded from the striking difference in length of the aortic and renal path that the resistance of the aortic path is comparatively greater than that of the renal path. The explanation is rather that the aorta has a greater relative diameter than all the other organs, and is to be regarded not so much as a pipe as an elastic reservoir with the function of an air vessel.

4. *The Comparative Physiology of the Cardiac Branches of the Vagus Nerve. By* Dr. W. H. Gaskell, *F.R.S.*

5. *On Rhythmical Variations in the Strength of the Contractions of the Mammalian Heart. By* Arthur R. Cushny.

Periodic variations in the force of the contraction of the auricle and ventricle occur after the injection of helleborein, as Knoll has pointed out. I have observed them after a number of other poisons, and occasionally during electrical stimulation of the dog's ventricle. The movements of the heart were registered by a modified form of the Roy Adami myocardiograph. These variations seem independent of any inhibitory action, and occur only when the ventricle contracts spontaneously in a different rhythm from the auricle, and so that during a complete period the rhythm of the ventricle exceeds that of the auricle by one complete contraction ($Rv = Ra + 1$). When the idioventricular rhythm gives rise to a regular auricular one, no periodic variations are observed. The ultimate cause of the variations is the alteration of the relation between the auricular and ventricular systoles. When the A*s* occurs in its normal position—during V*d*—both A*s* and V*d* are very complete, because the blood enters the ventricle freely, and the latter has not to dilate against a negative pressure, nor the auricle to contract against resistance. When the A*s* occurs during the V*s*, on the other hand, both are weakened, because the auricle has to contract against the systolic ventricular pressure, and, on the other part, the ventricle contracts against the resistance offered by the blood current entering it from the auricle. At the same time the auricle fails to supply blood to the ventricle during its relaxation, and the latter is therefore incomplete. The exit of the blood from the auricle is hindered, and it

therefore becomes much distended. Periods of large ventricular diastoles and systoles and large auricular systoles thereof alternate with others of small ventricular movements and weak systoles and great distension of the auricle.

These periods are best seen in the beginning of the irregular stage of poisoning with substances of the digitalis group, where the irritability of the ventricle has been increased just enough to cause a slightly more rapid rhythm than that supplied from the auricle. As the irritability is further augmented, the periods become shorter and less distinct. I have observed this periodic variation once (under caffein), where $Rv = Ra - 1$.

Occasionally another form of rhythmic irregularity occurs, in which $Rv = Ra - 2$. In this case a secondary period occurs during the primary one, and the whole period is distinctly less regular. When $Rv = Ra - 3$ the periodic variations become still more difficult to trace, and when the divergence between Rv and Ra is still greater all appearance of periodicity is lost.

In the normal heart the position of the As in the ventricular cycle varies from the first third of the diastole to the extreme end of the diastolic pause, and may even be prolonged into the ventricular systole. The efficiency of the heart must be affected by this factor, least work being wasted when the auricular systole corresponds with the first part of the ventricular relaxation, and a considerable amount of energy being expended in the mutual opposition of the auricle and ventricle, when the systole of the former overlaps into that of the latter.

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6. *Report on the Physiological Effects of Peptone and its Precursors.*

See Reports, p. 531.

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7. *The Absorption of Serum in the Intestine. By* E. Waymouth Reid, *Professor of Physiology in University College, Dundee.*

Heidenhain[1] demonstrated the fact that the water, organic and inorganic solids of serum introduced into the intestine, are absorbed.

The experiment was devised in support of the theory that intestinal absorption is possible under conditions in which osmotic transfer is excluded.

It was found that even inspissated serum is absorbed, and that at no time during the course of the experiment is a serum with a lower percentage of solids than that of the experimental animal found in the loop of gut, thus meeting the objection (so far as the absorption of the solids is concerned) that in such cases the serum introduced into the gut is diluted by water from the *succus entericus.*

Heidenhain omitted to measure the hydrostatic pressure on either side of the intestinal membrane, so that the possibility of the result being due to filtration was not excluded; and, indeed, the ancient filtration theory of *Lieberkühn*[2] has, with the necessary modern histological modifications, been revived of late by *Hamburger.*[3] In the experiments now described, the animal's own serum (obtained by the centrifugal machine) was introduced into a loop of its intestine, and the hydrostatic pressure in the cavity of the experimental loop, and in a mesenteric vein proceeding from a control loop, filled with 'normal saline' solution, observed continuously during the course of the experiment.

As will be seen from the cases quoted, water, organic and inorganic solids, are absorbed against considerable excess of hydrostatic pressure in the blood-vessels. (Since the velocity of the blood stream in capillaries is low, it is taken for granted that the pressure in the capillaries of the intestinal villi is not lower than that in a mesenteric vein at the border of the gut.)

The experiment presents practically the same features *when all the lacteals*

[1] *Pflüger's Archiv*, 1894, Bd. lvi. s. 579.
[2] *De fabrica et actione villorum*, 1757.
[3] *Du Bois-Reymond's Archiv*, 1896, s. 428.

leaving the experimental loop of intestine have been occluded by ligature. (See Experiments III. and IV.)

Experiment I.

Dog, 17·5 kilos. 80 cm. loop of gut. Duration of experiment, 1 hour.

		Organic Solids	Inorganic Solids
Introduced	50 c.c. of own serum holding	3·3500 grms.	·4500 grm.
Recovered	22 c.c. of serum holding	2·3474 grms.	·1870 grm.

Absorbed during the Hour.

Water	28 c.c.	i.e. 56·00 per cent.
Organic Solids	1·0026 grms.	i.e. 29·92 per cent.
Inorganic Solids	·2630 grm.	i.e. 58·45 per cent.

Pressures in mm. of Mercury.

Time	Vein	Gut
12.0 *Start*		
12.5	18·4	5·0
12.10	16·1	5·0
12.20	16·1	6·0
12.30	15·0	5·5
12.40	15·4	4·5
12.50	13·5	4·0
1.0 *Stop*		

Lowerings of Freezing-point.

Introduced Serum	Removed Serum	Serum of Dog at end of Experiment
$\Delta = \cdot 598$	$\Delta = \cdot 528$	$\Delta = \cdot 608$

Experiment II.

Dog, 20 kilos. 80 cm. loop of gut. Duration of experiment, 1 hour.

		Organic Solids	Inorganic Solids
Introduced	50 c.c. of own serum holding	3·4350 grms.	·4550 grm.
Recovered	18·5 c.c. of serum holding	2·0646 grms.	·1628 grm.

Absorbed during the Hour.

Water	31·5 c.c.	i.e. 63·00 per cent.
Organic Solids	1·3704 grms.	i.e. 39·89 per cent.
Inorganic Solids	·2922 grm.	i.e. 64·22 per cent.

Pressures in mm. of Mercury.

Time	Vein	Gut
12.5 *Start*		
12.10	10·7	2·0
12.20	11·5	2·0
12.30	11·1	2·0
12.40	11·5	3·0
12.50	11·4	3·0
1.0	*Clot*	3·0
1.5 *Stop.*		

Lowerings of Freezing-point.

Introduced Serum	Removed Serum	Serum of Dog at end of Experiment
$\Delta = \cdot 593$	$\Delta = \cdot 550$	$\Delta = \cdot 600$

Experiment III.

Dog, 22 kilos. 80 cm. loop of gut. Duration of experiment, 1 hour.

All Lacteals of Experimental Loop Ligatured.

	Organic Solids	Inorganic Solids
Introduced 50 c.c. of own serum holding .	3·6450 grms.	·4500 grm.
Recovered 25 c.c. of serum holding .	2·6080 grms.	·2220 grm.

Absorbed during the Hour.

Water	25 c.c.	i.e. 50·00 per cent.
Organic Solids	1·0370 grms.	i.e. 28·45 per cent.
Inorganic Solids	·2280 grm.	i.e. 50·67 per cent.

Pressures in mm. of Mercury.

Time		Vein	Gut
12·20	*Start*		
12·25	. . . .	15·4	3
12·35	. . . .	16·9	2·5
12·45	. . . .	17·3	2·5
12·55	. . . .	21·5	2·5
1·5	. . . .	16 9	2·0
1·15	. . . .	17·3	2·0
1·20	*Stop*		

Lowerings of Freezing-point.

Introduced Serum	Removed Serum	Serum of Dog at end of Experiment
Δ = ·615	Δ = ·580	Δ = ·590

EXPERIMENT IV.

Dog, 20 kilos. 80 cm. loop of gut. Duration of experiment, 1 hour.

All Lacteals of Experimental Loop Ligatured.

	Organic Solids	Inorganic Solids
Introduced 50 c.c. of own serum holding .	3·6830 grms.	·4570 grm.
Recovered 22·5 c.c. of serum holding .	2·6307 grms.	·2043 grm.

Absorbed during the Hour.

Water	27·5 c.c.	i.e. 55·00 per cent.
Organic Solids	1·0523 grms.	i.e. 28·57 per cent.
Inorganic Solids	·2527 grm.	i.e. 55·29 per cent.

Pressures in mm. of Mercury.

Time		Vein	Gut
12.20	*Start.*		
12.23	. . . .	18·4	1·5
12.30	. . . .	17·7–18·4	1·5
12.40	. . . .	19·2	4·0
12.50	. . . .	21·9	3·5
1.0	. . . .	20·8	3·5
1.10	. . . .	18·4	3·0
1·15	. . . .	16·9	3·0
1.20	*Stop.*		

Lowerings of Freezing-point.

Introduced Serum	Removed Serum	Serum of Dog at end of Experiment
Δ = ·600	Δ = ·598	Δ = ·603

No explanation of the above experiments is here attempted, but attention is briefly called to the following negative points :—

Osmosis, filtration into the blood capillaries, or into the lacteals by the action of Brücke's 'villus pump' are, it is considered, excluded by the conditions of the experiment.

That the disappearance of the serum from the cavity of the gut is simply a

matter of imbibition is in the highest degree improbable, because the cells must be, at the commencement of the experiment, soaked to the highest degree possible in those constituents of the animal's serum which they are capable of taking up.

Electro-osmotic action is again improbable, because secreting membranes produce ingoing electrical currents as well as absorbing membranes; and, to apply such an hypothesis, it would be necessary to assume that the ingoing current of the cells is active in one case (absorption), the outgoing return current in the other (secretion) involving the further hypothesis of some valvular nature of protoplasm with higher 'porosity' in the 'in-out' direction in the absorbing, and the 'out-in' direction in the secreting, membrane.

Finally, any aspirating action of the blood current in the capillaries of the villi is negligible on account of the low velocity of the current in capillary districts of the circulation.

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8. *The Function of the Canal of Stilling in the Vitreous Humour.* *By* Professor ANDERSON STUART.

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9. *Description of some pieces of Physiological Apparatus.* *By* Professor ANDERSON STUART.

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10. *On the Phosphorus Metabolism of the Salmon in Fresh Water.* *By* D. NOEL PATON, *M.D.*, *F.R.C.P.* (*Ed.*).

The observations here recorded form part of an extended study on the metabolism of the salmon in fresh water.

The method of investigation was to take for analyses sample salmon throughout the spring, summer, and autumn from the mouths of certain rivers, and other specimens from the upper waters of the same rivers, and by comparing these to arrive at conclusions as to the extent of the changes going on.

Observations made by Drs. Gulland, Gillespie, Dunlop, and myself clearly show that the fish do not feed during their stay in fresh water. The muscle substance steadily diminishes, while the ovaries and testes grow at its expense. The fats and proteids lost from the muscles are sufficient to supply these materials for the growing genitalia, and to yield a very large amount of energy for muscular work.

The question here discussed is the Exchange of Phosphorus.

It is first shown that in muscle the phosphorus is chiefly in the form of inorganic phosphates, though a comparatively large amount of lecithin and a small amount of nuclein are also present.

In the ovary the phosphorus is chiefly combined in the pseudo-nuclein—ichthulin; but it is also present in considerable amounts in lecithin, and in very small amounts as inorganic phosphates.

In the testis the phosphorus is chiefly in the form of true nucleins, but there are also a considerable quantity of lecithin and a small quantity of inorganic phosphate.

As the season advances the phosphorus in the genitalia increases, while the phosphorus of the muscle diminishes. The loss of phosphorus from the muscle is barely sufficient to account for the gain in the ovary, amply sufficient to yield the increase of phosphorus in the testis. The lecithin lost from the muscle is sufficient only to account for a small part of the lecithin gained by the ovary. The lecithin and ichthulin of the ovary must thus be found by synthesis as these structures grow. The nuclein of the testis must be formed in a similar manner.

The presence of considerable amounts of lecithin in the growing ovary and testis would seem to indicate that this substance is one of the first stages in the construction of nucleo compounds.

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11. *Electrostatical Experiments on Nerve Simulating the effects of Electric Rays.* *By* Professor JACQUES LOEB.

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12. *The Gastric Inversion of Cane Sugar by Hydrochloric Acid.*[1] *By* Professor GRAHAM LUSK.

For thirty-five years it has been shown upon the lecture table of Voit that a 0·3% hydrochloric acid solution at the temperature of the body has the power of rapidly inverting cane sugar. After feeding an animal with cane sugar, that and invert sugar are found in the stomach, while only invert sugar is to be detected in the intestinal canal. No inverting enzyme has been found in the stomach similar to that present in the small intestines. The question to be solved was this: is the acid of the gastric juice a sufficient agent to accomplish such inversion of cane sugar as takes place within the stomach? The following table shows in per cent. the amount of cane sugar inverted after standing different lengths of time, with different strengths of acid, at a temperature of 38-40° C.

	0·91% cane sugar	0·95% sugar	0·91% sugar	5% sugar	0·91% sugar
Time	0·1% HCl.	0·2% HCl.	0·2% HCl.	0·2% HCl.	0·3% HCl.
1 hour		14·0		15·5	22·2
2 hours		25·4		29·9	37·6
3 ,,		30·9		34·2	49·5
4 ,,	26·5		37·8	43·0	58·9
5 ,,			47·5	59·6	64·8
7 ,,	40·0		76·8	69·2	79·3
10 ,,			81·7		93·4
12 ,,	63·8		86·4		94·1

The results show the stronger the acid the greater the inversion. In general about the same percentage of inversion is obtained with a 5% sugar solution as with a 0·91% solution. The amount of cane sugar inverted by the same acid is thus proportional to the strength of the sugar solution. Hence, as the sugar solution becomes more and more changed by inversion, the quantity to be acted on becomes smaller, and therefore the quantity inverted grows less. This is according to Wilhelmy's law of chemical change. It has also been determined that proteid (white of eggs) and proteolytic digestive products in acid combination with hydrochloric acid (*i.e.*, when the solution gives no tropæolin reaction) have almost the same inverting action as free hydrochloric acid. Comparing these experiments with results already obtained from living animals, the conclusion is drawn that the acidity of the gastric juice is itself sufficient to produce such inversion as takes place in the stomach. Many of the analyses given above were made by Dr. S. J. Ferris.

SATURDAY, AUGUST 21.

The Section did not meet.

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[1] The Paper will be published in the *Am. Journ. of Physiology.*

MONDAY, AUGUST 23.

The following Papers were read:—

1. *Study of the Comparative Physiology of the Cells of the Sympathetic Nervous System.* *By* Professor G. CARL HUBER.

The sympathetic neurons are multipolar in all vertebrates except the amphibia, where the nerve cells are unipolar. The dendrites of the multipolar sympathetic neurons form an intercellular plexus (between the cell-bodies of the sympathetic neurons constituting the ganglion) and a general peripheral plexus under the capsule of the ganglion. The neuraxes of sympathetic neurons terminate either in involuntary muscle, in heart muscle, in glandular tissue, in the spinal root-ganglion, and possibly also in other sympathetic ganglia.

Terminating in the sympathetic ganglia are found small medullated nerve fibres, first correctly described by Gaskell, then by Langley and others, which leave the cerebro-spinal axis through the anterior or motor roots of the dorsal and three or four upper lumbar nerves and constitute the white rami communicantes. That these nerve fibres end in the ganglia has been shown by Langley and others by the nicotin-method.

They end by forming pericellular, intracapsular plexuses, which, while they may show a slight variation in structure in the different vertebrates, may nevertheless be regarded as similar in all vertebrates.

The sympathetic neuron forms, therefore, a terminal link in a neuron-chain of which the second link is formed by a neuron the neuraxis of which constitutes the neuraxis of a nerve-fibre in a white ramus.

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2. *Investigations in the Micro-chemistry of Nerve Cells.* *By* J. J. MACKENZIE.

It was found that the Nissl granulations in nerve cells were distinctly iron-holding, and consequently related to the iron-holding chromatins of the nucleus.

Pathological cells from rabbits, inoculated with rabies, were studied for comparison, and it was found that as long as basophil granulations were present in the cell, it was possible to obtain an iron reaction in them. In the motor cells of the cortex, in rabid animals, it was found that oxyphil granulations appeared in the situations which the Nissl granulations had occupied, and that these oxyphilic granules were very slightly iron-holding. It seemed probable that there was a conversion of iron-holding basophil granules into oxyphil granules containing little iron.

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3. *An Investigation of the changes in Nerve Cells in various Pathological conditions.* *By* W. B. WARRINGTON, *M.D.* (*Lond.*), *M.R.C.P.*
See Reports, p. 525.

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4. *Action of Reagents on Isolated Nerve.* *By* Dr. A. WALLER, *F.R.S.*
See Reports, p. 518.

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5. *Action of Anæsthetics on Nerve.* *By* F. S. LLOYD.
See Reports, p. 520.

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6. *Action of Anæsthetics on Cardiac Muscle.* *By* Miss WELBY.

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7. *Période Réfractaire dans les Centres Nerveux.*[1] *Par* Professor Dr. C. Richet.

J'ai pu, avec la collaboration d'André Broca, démontrer qu'il y a dans les centres nerveux cérébraux et médullaires (chez le chien) une *période réfractaire.* On ne connaissait jusqu'ici ce phénomène que pour le cœur; il est important de constater qu'il existe, avec une netteté plus grande encore que pour le cœur, dans les cellules nerveuses.

Soit un chien, refroidi à 30°, et, pour l'immobilisation et l'insensibilité, anesthésié avec du chloralose (0·10 grm. par kilogrm.); il répondra aux excitations cérébrales électriques, si celles-ci ne sont pas trop fréquentes, par des réponses musculaires isolées. La plupart des physiologistes n'ont étudié que les excitations fréquentes. Voyons les effets des excitations isolées.

Si elles sont rythmées à 1 par seconde, elles sont égales; mais, si elles sont rythmées à 4 par seconde, il y en aura une grande et une petite, et enfin, si elles sont rythmées à 10 par seconde, il n'y aura plus de réponse à chaque excitation, mais seulement 1 réponse sur 2. Il se fait alors un rythme qui est dans un rapport simple avec le rythme excitateur $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, selon les cas, suivant la rapidité des excitations.

Ainsi, dans certaines conditions, *sur deux excitations l'animal ne répond qu'à une seule, car la seconde tombe dans la période réfractaire.*

Même avec les excitations mécaniques le résultat est identique. Un chien chloralosé répond à chaque excitation mécanique de la table sur laquelle il repose par une contraction convulsive soudaine. Mais s'il est refroidi, et si on fait des ébranlements fréquents de la table, *il ne répond plus qu'à une secousse sur deux.*

On peut établir qu'il s'agit là d'un phénomène analogue à celui que les physiciens ont appelé *l'amortissement des vibrations et synchronisation des oscillants.* De fait dans l'étude du système nerveux on ne s'était pas préoccupé de l'élément physique de la vibration nerveuse, et on avait surtout envisagé l'élément chimique. Mais il est nécessaire qu'une vibration s'éteigne après qu'elle a eu lieu, de sorte que cette période d'extinction de la vibration est la période réfractaire.

Pour amortir une vibration, il semble que le mode adopté par la nature soit celui d'une courbe avec retour graduel à l'état d'équilibre, au lieu du retour par une série d'oscillations de plus en plus petites. C'est le procédé que Lord Kelvin a adopté pour l'amortissement des oscillations électriques dans la transmission des dépêches par cable sous-marin.

La durée de cette période réfractaire est d'un dizième de seconde chez ces chiens normaux.

Chez les chiens refroidis à 30° elle est de 0·5 sec.

On la mesure en saisissant le moment où deux secousses consécutives sont égales entre elles. Chez un chien refroidi à 30°, il suffit que les excitations cérébrales soient distantes de moins de 0·5 sec pour que les deux réponses musculaires soient inégales.

On peut prouver qu'il y a chez l'homme une période réfractaire, en ce sens que des excitations cérébrales (ou des volitions) isolées ne peuvent avoir un rythme plus fréquent que 10 ou 11 par seconde. On peut s'en convaincre en essayant de *penser* une gamme musicale, par exemple, ou une série de voyelles ou de mots, avec le maximum de rapidité, et on verra qu'on ne dépasse pas 11, ou 12 tout au plus, par seconde.

Nous avons donc par cette constatation et cette mesure de la période réfractaire déterminé la durée de la vibration nerveuse; et par là établi en quelque sorte *l'unité psychologique du temps.*

La conscience, résultat de l'activité nerveuse, a donc une *période élémentaire; et cette période élémentaire est d'environ un dizième de seconde.*

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8. *On a Cheap Chronograph.* *By* Professor W. P. Lombard.

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[1] Vois, pour plus de details, *Archives de Physiologie,* 1897, No. 4, p. 870, et *Dict. de Physiologie,* art. cerveaux, t. iii., p. 17–44.

9. *Demonstration of the Pendulum Chronoscope and Accessory Apparatus. By* Dr. E. W. Scripture, *Yale University.*

The pendulum chronoscope contains, in the first place, an accurately adjusted double-bob pendulum. This pendulum is held by a catch at the right-hand side. In making an experiment this catch is pressed noiselessly and the pendulum starts its swing. It carries along a light pointer held in position by a delicate spring. At a definite moment it presses a delicate catch which releases the mechanism beneath the base. This mechanism is adjusted to do several things: one of them is to drop a shutter which covers an opening at the back of the chronoscope. The person experimented upon is seated at the back; owing to the curtain he can see nothing but the covered opening. He finds before him a rubber button like that on a telegraph-key. He is to press this button as soon as he sees the shutter expose the opening. He does so, and another mechanism releases a horizontal bar running behind the scale. The pointer swings between this bar and the scale, and is consequently stopped when the bar snaps against the scale. The zero-point is passed at the moment the shutter starts to fall; the marks on the scale indicate the number of thousandths that elapse till the button is pressed. The instrument is built with the greatest accuracy. For reaction to light, coloured cards or pieces of transparent celluloid are inserted into a holder just behind the shutter.

The reactions to light are not disturbed by noises, as the pendulum makes no noise either at release or during its swing, and the shutter makes only a faint sound.

For reactions to sound without further apparatus, the shutter is arranged to strike with a noise. In this case a constant quantity is subtracted from the scale. For these reactions it is generally preferable to insert a telephone with a battery in circuit with the platinum contact about to be described.

The shutter rests against a platinum point in such a way that its movement can be used to break an electric circuit; this can be used for producing lights, sounds, electric shocks, &c. A strong electro-magnet is placed beneath the base in such a way that it can take the place of the button; thus the pointer can be caught by the movement of a key in the hands of a distant person. An arrangement is also provided whereby the pendulum itself is released electrically. Still further mechanisms are added for various purposes.

Among the accessory apparatus are a newly invented lamp battery, a simple, cheap and convenient arrangement which changes a high voltage dynamo current into a low voltage current suitable for ordinary battery purposes—*e.g.*, to run tuning forks, telegraph instruments, bells, &c.

[For a full account of the chronoscope see Scripture, 'New Psychology,' p. 155, London, 1897: and of the lamp batteries see 'Studies from the Yale Psychological Laboratory,' vol. iv., p. 76.]

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10. *The Tricolour Lantern for Illustrating the Physiology and Psychology of Colour-vision. By* Dr. E. W. Scripture, *Yale University.*

By means of special triple slides and accessory apparatus, the fundamental laws of colour-vision can be demonstrated. The newer theory of colour-blindness is illustrated by some specially devised slides.

[A full description of the lantern is given in the author's 'New Psychology,' p. 348.]

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11. *Observations on Visual Contrast. By* C. S. Sherrington, *M.A., M.D., F.R.S., Liverpool.*

1. On a parti-coloured disc let two concentric circular bands, each composed of the same two colours alternately disposed, be inscribed, and the arrangement of the component colours be such as to, in one band (A), minimise the contrast of the

colours, and in the other (B) to accentuate it. On whirling the disc, it is found that the rate of revolution required to fuse the component colours in ring-band A is less than that required for ring-band B. In this way the heightened contrast between the colours is found to take effect when all knowledge of the contrast between their components and the background has been eliminated from consciousness. Judgment is thereby eliminated from the effect, and the relation of judgment to simultaneous contrast decided against the Helmholtz view and in favour of the Hering view.

A measurement of the degree of simultaneous contrast may be obtained from the rate of rotation required for fusion.

2. On a parti-coloured disc two concentric circular bands, each composed of the same two component tints, are so inscribed that the darker component of one (A) is to a certain extent deepened in tint by simultaneous contrast against the background. On spinning the disc it is found that the ring-band (A) appears darker than its fellow ring-band, although physically the intensity of the components are exactly equal in the two. This visual darkening is apparent when all knowledge of the existence of simultaneous contrast has been dismissed by fusion of the components of the background by rapid translation of the surface.

3. On a disc half black half white let two short black arcs jut from the black into the white half, and at the opposite radius two counterpart white arcs jut into the black half. These pairs are so placed as to compensate one for the other; throughout the entire disc the angular quantities of black and white are equal. On spinning the disc the rate of intermission sufficient to extinguish 'flickering' in the sensation obtained might be expected to be the same for all parts of the disc. This is not the case. In one direction of spin, the rate of rotation required to fuse the ring-bands possessing the jutting black arcs is higher than that required for the intermediate ring-band on the disc; in the opposite direction the reverse. Successive contrast is here adding its effect to simultaneous contrast: the latter is here, as in the previous experiments, obviously taking effect, although rapid translation of the surface has removed all possibility of the observer being aware of its existence on the disc.

4. On a disc half white half black two short red arcs (A and B) are inscribed in the black half at different radial distances, and two similar short arcs of black (A′ and B′) are inscribed in the white half, A′ and A, B and B,′ being at the same radial distances. On being whirled the tints of the two ring bands are found to differ in brightness, even when in an ordinarily lighted room, the rate of intermission is as rapid as 50 times a second. This difference seems explicable by successive contrast, and indicates that even after a fiftieth of a second exposure to black, the eye has been more sensitive to white, and conversely after a fiftieth of a second exposure to moderate white.

5. On a disc of 160° white and 200° black, let some short and rather narrow arcs of red be placed on the white sector where it abuts on the black. Let half the number of red arcs lie at one border of the white near the edge of the disc, the other at the other border near the centre of the disc. When studied by lamp light (yellowish illumination) one of the sets of arcs will, on spinning the disc somewhat slowly, seem much less bright than the other set, and the grey of the disc in the spaces between the arcs of visually darker red will appear bluish-green; in the spaces between the visually brighter red arcs will appear pale yellow. This yellow appears due to a development of a positive after-image, the blue chiefly to a negative image, but also in part probably to simultaneous contrast. On whirling the disc at higher speed, the tints of the two red bands, also of the intermediate bands, approximate, both the latter two becoming pale greenish-blue. At still higher speeds the red bands become fully alike, and the intermediate bands become completely similar pale green-blue bands. At this rate the intermittence has become too frequent to permit the influence of rebound effects, and successive contrast has been eliminated, simultaneous contrast alone remaining. But the rate required to do this is higher in certain discs than one-fiftieth of a second. By thus using the discs as rheotom for the visual sensations, it is found that a perceptible after-image is formed after a very moderately intense stimula-

tion in less than one-fiftieth of a second. The method shows also that from one-fiftieth of a second up to a quarter of a second after its commencement this after-image continues perceptibly increasing in intensity.

TUESDAY, AUGUST 24.

A combined meeting of Sections I and K for the discussion of the Chemistry and Structure of the Cell was opened by the reading of the following Papers:—

1. *On the Rationale of Chemical Synthesis.* *By* Professor R. MELDOLA, *F.R.S.*

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2. *On the Existence in Yeast of an Alcohol-producing Enzyme.* *By* Professor J. R. GREEN, *F.R.S.*

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3. *New Views on the Significance of Intra-cellular Structures and Organs.* *By* Professor A. B. MACALLUM, *Ph.D.*

WEDNESDAY, AUGUST 25.

The following Papers were read:—

1. *Preliminary Account of the Effects upon Blood-pressure produced by the Intra-venous Injection of Fluids containing Choline, Neurine, or Allied Products.* *By* F. W. MOTT, *M.D., F.R.S., and* W. D. HALLIBURTON, *M.D., F.R.S.*

The experiments have been conducted as follows:—The animals used were dogs anæsthetised with ether. The right external jugular vein and the left carotid artery were exposed, and a cannula was introduced into each vessel. The artery was connected with a mercurial manometer in the usual way for taking a blood-pressure tracing. A simultaneous tracing of the respiratory movements was taken by the tambour method.

The fluids were injected into the vein, and the results were, with certain exceptions to be afterwards mentioned, in all cases similar—viz., no marked effect upon respiration, but a marked temporary fall in the blood-pressure, which begins about 10 seconds after the commencement of the injection.

The fluids we used were—

(1) Normal cerebro-spinal fluid. This produced no effect.

(2) Cerebro-spinal fluid obtained *post mortem* from a considerable number of cases of general paralysis of the insane, from one case of stuporose melancholia, and from one case of cerebral hæmorrhage owing to the giving way of a cortical cerebral vessel.

To avoid fallacy of decomposition from microbic growth, it may be stated that the bodies were placed in a cold chamber (0° C. or below that) within half an hour of death, and cultures were in all cases made from the cerebro-spinal fluid and blood of the frontal sinus, and in nearly all instances without result. This is necessary, because many of these people die with bladder affection or ulcerative colitis, and microbic toxins might arise.

As a rule, 10 c.c. of the fluid were injected; and although the effect varied somewhat in degree, yet in only one instance did no fall in the blood-pressure

occur. That instance was the cerebro-spinal fluid from the case of cortical hæmorrhage, an acute case with no naked-eye wasting of the brain substance.

(3) The cerebro-spinal fluid was boiled and filtered, and the filtrate gave the same result. It could not, therefore, be due to proteid.

(4) The cerebro-spinal fluid was mixed with several times its volume of alcohol, by which all proteids and proteoses would be precipitated. It was filtered, and the filtrate dried at a temperature of about 40° C., and the residue dissolved in saline solution. This, when injected, gave a similar fall in the blood-pressure.

(5) Solution of neurine hydrochloride 0·1 per cent. solution. 2·5 c.c. gave a similar fall; but in most instances this was followed by a return to or even above the original pressure and then a second fall[1] which persisted to some extent, a condition we never observed with the cerebro-spinal fluid. This result is similar to that previously obtained by Schäfer and Oliver. Stronger doses produce marked slowing of the heart, and slowing and deepening of the respiration. The fatal dose is less than a decigramme, respiration ceasing before the heart.

(6) Solution of choline hydrochloride 0·2 per cent. solution. 5 c.c. gave a result identical as far as we could observe with that obtained by the pathological cerebro-spinal fluids. With stronger doses there is slowing of the heart.

(7) The blood obtained from patients suffering from pseudo-apoplectiform convulsions of general paralysis obtained by venesection was mixed with several times its volume of absolute alcohol, filtered, and the filtrate evaporated to dryness at about 40° C. The residue was dissolved in saline solution and a quantity was injected corresponding to 50 c.c. of the original blood in each case. The result obtained corresponded entirely with that obtained with the pathological cerebro-spinal fluids and with *solution of choline.* Normal blood similarly treated gave a negative result.

It may be added that section of the vagi has no influence on the fall of blood-pressure produced by the injection.

The substance in the pathological cerebro-spinal fluid which produces the effect is precipitable by phosphotungstic acid; it is therefore probably alkaloidal in nature. Normal cerebro-spinal fluid after removal of the proteid gives no precipitate with phosphotungstic acid. The pathological cerebro-spinal fluids we have examined are rich in coagulable proteid, contain no proteose or peptone, and are usually free from reducing substance. The reducing substance of the normal fluid was considered by one of us to be allied to or identical with pyrocatechin. In small doses pyrocatechin produces no effect on blood-pressure; in large doses it causes a very slight fall.

The disintegration of the nerve-cells of the brain in the cases from which the fluid was obtained can be demonstrated best by Nissl's method.

We have also taken tracings of blood-pressure simultaneously with plethysmographic tracings of the limbs, and of the kidney, an air oncometer being used in connection with the latter organ. There is no peripheral dilatation of the blood-vessels. That the fall of blood-pressure is cardiac in origin was confirmed by experiments on the frog's and mammal's heart. This conclusion fits in very well with what is found in general paralysis of the insane; cardiac weakness and enfeebled circulation are commonly observed; and fatty degeneration of the heart is very frequently discovered *post mortem.*

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2. *On the Distribution of Iron in Animal and Vegetable Cells.* *By* Professor A. B. MACALLUM, *Ph.D.*

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3. *On the Presence of Copper in Animal Cells.* *By* Professor W. A. HERDMAN, *F.R.S., and* Professor RUBERT BOYCE.

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[1] By the plethysmographic method this second rise and fall are found to be produced by a constriction followed by a dilatation of the peripheral blood-vessels.

4. *On Internal Absorption of Hæmoglobin and Ferratin.* *By* F. W. G. Mackay.

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5. *On Secretion in Gland Cells.* *By* R. R. Bensley.

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6. *The Morphology and Physiology of Gastric Cells.* *By* R. R Bensley.

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7. *Visual Reaction to Intermittent Stimulation.* *By* O. F. F. Grünbaum.

The factors upon which fusion of intermittent retinal stimuli depends have apparently been noted singly, and never collectively considered.

Schafhautl found that, on increasing the strength of the stimuli, increase in frequency was necessary to produce fusion: speed of translation was observed by Filehne to have an effect.

Charpentier and Baader pointed out that the size of the field of vision was an important factor, and Sherrington has recently demonstrated the effects produced by simultaneous contrast.

Experiments have been made, bearing in mind the above facts, along with the necessity of guarding against fatigue.

It was found that if the field of vision were small, so that the image fell entirely within the fovea, and the speed of translation great, it was impossible to discern that the stimulus was intermittent above sixty-three alternations per second.

It must be noted that when the source of light is within focal range, and of a nature that can be focussed, there is no sudden transition from the recognised coarse flicker to that of a smooth, steady sensation, but an intermediate stage of fine flicker or tremor of the field is experienced.

If the stimulus be greatly increased, the maximum frequency at which discontinuity of stimulation is observed may fall to forty-five alternations per second before pathological phenomena ensue.

If the speed of translation be small, discontinuity of stimulation may be observed at 500 alternations per second, with practice, but then only through a short range of luminosity. On increasing the strength of stimuli, the frequency must be rapidly diminished in order to discern discontinuity.

The effect of speed of translation is well shown by keeping the luminosity constant, and using rotating discs with varying numbers of sectors: it is then found that one with many sectors, and consequently a slow speed of translation, will require a high frequency of alternation to produce fusion, while one with but few sectors will fuse with a frequency of alternation of sixty-three per second or below. This is probably due to unconscious simultaneous contrast.

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8. *Functional Development of the Cerebral Cortex in Different Groups of Animals.* *By* Wesley Mills, *M.A., &c., Professor of Physiology in McGill University, Montreal.*

The purpose of the research described in this Paper is to determine whether the cerebral cortex is functional at birth, and, if not, then how soon afterwards in several species of animals, those being selected that are most commonly employed for physiological experiments and are best known.

The method of investigation was described, illustrated protocols of experiments given, and inferences drawn for each species of animal the subject of experiment.

The paper concluded with a criticism of the work of other investigators, and with some general deductions.

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9. *The Psychic Development of Young Animals and its Somatic Correlation, with special reference to the Brain.* *By* WESLEY MILLS, *M.A., M.D., &c., Professor of Physiology in McGill University, Montreal.*

This Paper is founded on the previous one, and a series of investigations made on the psychic development of young animals, and is an attempt to correlate the results.

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10. *The Physiology of Instinct.* *By* Professor C. LLOYD MORGAN, *F.G.S.*

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11. *The Nature and Physical Basis of Pain.* *By* Professor L. WITMER.

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12. *The Action of Glycerine on the Tubercle Bacillus.* *By* S. MONCKTON COPEMAN, *M.A., M.D. (Cantab.), and* F. R. BLAXELL, *M.D. (Lond.).*

(From the Bacteriological Laboratory of Westminster Hospital Medical School.)

At the last meeting of the Association, held at Liverpool in 1896, a report on the influence of glycerine on the vital activity of certain micro-organisms was presented to this Section. In that Paper we showed that the presence of glycerine to the extent of 40 per cent. in culture media, such as peptone beef broth, sufficed to kill out, in various periods of time, certain pathogenic microbes, including the *Pyogenic cocci, Streptococcus Pyogenes, Streptococcus Erysipelatosus, Bacillus Tuberculosis, B. Typhosus and B. Diphtheriæ,* the maximum resistance being overcome in about three weeks. On the other hand, the spores of the common *Hay Bacillus* were shown to be capable of resisting the action of glycerine considerably longer, as also was the *B. Coli Communis* when kept at low temperatures. Samples of small-pox and vaccine material, in the form of lymph and 'crusts,' were also employed, and were found to have become freed from extraneous micro-organisms within comparatively short periods, when exposed to the influence of 40 per cent. glycerine.

During the past year we have instituted further experiments in this direction, working especially with the *Bacillus Tuberculosis,* with the object of determining whether this micro-organism can survive and remain capable of further development after a sojourn, for varying periods, in glycerinated vaccine lymph.

METHOD.—Vaccine material was rubbed up in the usual way with a mixture of glycerine and water, the greater part of the resulting emulsion (containing glycerine to the extent of 42 per cent.) being then filled into small tubes. To the residue, amounting to about 4 c.c., was added a large quantity of growth from a recently isolated and virulent culture of Tubercle Bacilli. This growth was thoroughly mixed with the emulsion, and the whole was poured into two small tubes, which were corked and placed in a cool, dark cupboard with the rest of the tubed emulsion. At the same time, from the tubercle culture, control inoculations were made in tubes of 6 per cent. glycerine agar-agar, and in tubes of 6 per cent. peptone beef broth. These were incubated part at body temperature, and part at that which ordinarily obtained in the laboratory. At the end of a month the emulsion was demonstrated by the method of plate cultivation to be free from extraneous microbes. Similarly plates poured from the small tubes containing the tubercle culture also showed no growth. Numerous inoculations were made on the surface of 6 per cent. glycerine agar, and on solidified blood serums, the tubes being then incubated at 37° C. After a month's incubation, no growth resulted from any of these inoculations.

Lest traces of glycerine carried over by the inoculation needle should have retarded or prevented the growth of the Tubercle Bacillus, some of the emulsion originally contaminated with tubercle was mixed with sterile beef-broth, and from

this numerous inoculations were made and incubated at 37° C. These also, after the lapse of a month, failed to show any sign of growth. Control tubes, inoculated from the original tubercle culture employed in the whole series of experiments, and incubated at 37°C., all exhibited a copious growth in a month, and subcultures from them were all, in turn, successful.

As the result of a lengthy series of experiments on the lines described, it has been found impossible to recover Tubercle Bacilli after exposure for a month to the action of an intimate admixture of glycerine to the extent of 40 per cent., either with sterile beef-broth or with fresh vaccine material.

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13. *Inhibition as a Factor in Muscular Co-ordination. By* Professor C. S. SHERRINGTON, F.R.S.

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14. *A Movement produced by the Electric Current. By* Professor F. BRAUN.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION.—H. MARSHALL WARD, D.Sc., F.R.S., Professor of Botany in the University of Cambridge.

The President delivered the following Address on Friday, August 20:—

THE competent historian of our branch of science will have no lack of materials when he comes to review the progress of botany during the latter half of the Victorian reign. The task of doing justice to the work in phanerogamic botany alone, under the leadership of men like Hooker, Asa Gray, Mueller, Engler, Warming, and the army of systematists so busily shifting the frontiers of the various natural groups of flowering plants, will need able hands for satisfactory treatment. A mere sketch of the influence of Kew, the principal centre of systematic botany, and of the active contingents of Indian and colonial botanists working under its inspiration, will alone require an important chapter, and it will need full knowledge and a wide vision to avoid inadequacy of treatment of its powerful stimulus on all departments of post-Darwinian botany. The 'Genera Plantarum,' the 'British Flora,' the 'Flora of India,' suffice to remind us of the prestige of England in systematic botany, and the influence of the large and growing library of local and colonial floras we owe to the labours of Bentham, Trimen, Clarke, Oliver, Baker, Hemsley, Brandis, King, Gamble, Balfour, and the present Director of Kew, is more than merely imperial.

The progress in Europe and America of the other departments of botany has been no less remarkable, and indeed histology and anatomy, comparative morphology, and the physiology and pathology of plants have perhaps advanced even more rapidly, because the ground was newer. In England the work done at Cambridge, South Kensington and elsewhere, and the publications in the 'Annals of Botany' and other journals sufficiently bear witness to this. A consequence has been the specialisation which must soon be openly recognised—as it already is tacitly—in botany as in zoological and other branches of science.

No note has been more clearly sounded than this during the past twenty-five years, as is evident to all who have seen the origin, rise, and progress of our modern laboratories, special journals, and even the gradual subdivisions of this Association. We may deplore this, as some deplore the departure of the days when a naturalist was expected to teach geology, zoology, and botany as a matter of course; but the inevitable must come. Already the establishment of bacteriological laboratories and a huge special literature, of zymo-technical laboratories and courses on the study of yeasts and mould fungi, of agricultural stations, forestry and dairy schools, and so on—all these are signs of the inexorable results of progress.

There are disadvantages, as the various *Centralblätter* and special journals show; for hurried work and feverish contentions for priority are apt to accompany these subdivisions of labour; and those of us who are most intimately concerned with the teaching of botany will do well to take heed of these signs of our times, and distinguish between the healthy specialisation inevitably due to the sheer weight and magnitude of our subject, and that incident on other movements and arising from other causes. The teaching and training in a university or school need not be narrow because its research-laboratories are famous for special work.

One powerful cause of modern specialisation is utility. The development of industries like brewing, dyeing, forestry, agriculture, with their special demands on botany, shows one phase; the progress of bacteriology, palæontology, pathology, economic and geographical botany, all asking special questions, suggests another. In each case men are encouraged to go more and more deeply into the particular problems raised.

Identification of flowers in Egyptian tombs, of pieces of wood in Roman excavations, the sorting of hay-grasses for analysis, or seeds in the warehouses; the special classifications of seedlings used by foresters, or of trees in winter, and so on, all afford examples. It is carried far, as witness the immense labour it is found worth while for experts to devote to the microscopic analysis of seeds and fruits liable to adulteration, or to the recognition of the markings in imprints of fossil leaves, or of characters like leaf-scars, bud-scales, lenticels, and so on, by which trees may be determined even from bits of twigs.

If we look at the great groups of plants from a broad point of view, it is remarkable that the Fungi and the Phanerogams occupy public attention on quite other grounds than do the Algæ, Mosses, and Ferns. Algæ are especially a physiologists' group, employed in questions on nutrition, reproduction, and cell-division and growth; the Bryophyta and Pteridophyta are, on the other hand, the domain of the morphologist concerned with academical questions such as the Alternation of Generations and the Evolution of the higher plants.

Fungi and Phanerogams, while equally or even more employed by specialists in Morphology and Physiology, appeal widely to general interests, and evidently on the ground of utility. Without saying that this enhances the importance of either group, it certainly does induce scientific attention to them.

I need hardly say that comparisons of the kind I am making, invidious though they may appear, in no way imply detraction from the highest honour deservedly paid to men who, like Thuret, Schmitz, and Thwaites in the past, and Bornet, Wille, and Klebs in the present, have done and are doing so much to advance our academical knowledge of the Algæ; and Klebs' recent masterpiece of sustained physiological work, indeed, promises to be one of the most fruitful contributions to the study of variation that even this century has produced. Nor must we in England forget Farmer's work on *Ascophyllum*, and on the nuclei and cell-divisions of *Hepaticæ*; and while Bower and Campbell have laid bare by their indefatigable labours the histological details of the Mosses and Vascular Cryptogams, and carried the questions of Alternation of Generations and the evolution of these plants so far, that it would almost seem little remains to be done with Hoffmeister's brilliant conception but to ask whither it is leading us; the genetic relationships have become so clear, even to the details, that the recent discovery by Ikeno and Hirase of spermatozoids in the pollen tubes of *Cycas* and *Gingko* almost loses its power of surprising us, because the facts fit in so well with what was already taught us by these and other workers.

It is impossible to over-estimate the importance of these comparative studies, not only of the recent Vascular Cryptogams, but also of the Fossil Pteridophyta, which, in the hands of Williamson, Scott, and Seward, are yielding at every turn new building stones and explanatory charts of the edifice of Evolution on the lines laid down by Darwin.

All these matters, however, serve to prove my present contention, that the groups referred to do not much concern the general public; whereas, on turning to the Fungi and Phanerogams, we find quite a different state of affairs. It is very significant that a group like the Fungi should have attracted so much scientific

attention, and aroused popular interest at the same time. In addition to their importance from more academical points of view—for they claim the attention of morphologist and physiologist as much as any group, as the work of Wager, Massee, Trow, Hartog, and Harper, and an army of Continental investigators, with Brefeld, Von Tavel, Magnus, &c., at their head, has shown—the Fungi appeal to wider interests on many grounds, but especially on that of utility. The fact that Fungi affect our lives directly has been driven home, and whether as poisons or foods, destructive moulds or fermentation-agents, parasitic mildews or disease germs, they occupy more of public interest than all other Cryptogams together, the flowering plants alone rivalling them in this respect.

A marked feature of the period we live in will be the great advances made in our knowledge of the uses of plants. Of course, this development of Economic Botany has gone hand in hand with the progress of Geographical Botany and the extension of our planting and other interests in the colonies, but the useful applications of Botany to the processes of home industries are increasing also.

The information acquired by travellers exploring new countries, by orchid-collectors, prospectors for new fibres or india-rubber, or resulting from the experiences of planters, foresters, and observant people, living abroad, has a value in money which does not here concern us; but it has also a value to science, for the facts collected, the specimens brought home, the processes observed, the results of analyses, the suggestions gathered—in short, the puzzles propounded by these wanderers—all stimulate research, and so have a value not to be expressed in terms of money.

The two react mutually, and I am convinced that the stimulus of the questions asked by commerce of botanical science has had, and is having, an important effect in promoting its advance. The best proof to be given of the converse—that botany is really useful to commerce—is afforded by the ever-increasing demands for answers to the questions of the practical man. At the risk of touching the sensibilities of those who maintain that a university should regard only the purely academical aspects of a science, I propose to discuss some cases where the reciprocal influences of applied, or useful, and purely academic or useless botany—useless because no use has yet been made of it, as some one has wittily put it—have resulted in gain to both. In doing this, I wish to clearly state my conviction that no scientific man should be guided or restricted in his investigations by any considerations whatever as to the commercial or money value of his results: to patent a method of cultivating a bacillus, to keep secret the composition of a nutritive medium, to withhold any evidence, is anti-scientific, for by the nature of the case it is calculated to prevent improvement—*i.e.* to impede progress. It is not implied that there is anything intrinsically wrong in protecting a discovery: all I urge is that it is opposed to the scientific spirit.

But the fact that a scientific discovery is found to have a commercial value also—for instance, Wehmer's discovery that the mould fungus, *Citryomyces*, will convert 50 per cent. of the sugar in a saccharine solution to the commercially valuable citric acid; or Matruchot's success in germinating the spores of the mushroom, and in sending pure cultures of that valuable agaric into the market—is no argument against the scientific value of the research. There are in agriculture, forestry, and commerce generally, innumerable and important questions for solution, the investigation of which will need all the powers of careful observation, industrious recording, and thoughtful deduction of which a scientific man is capable. But while I emphatically regard these and similar problems as worthy the attention of botanists, and recognise frankly their importance, I want to carefully and distinctly warn all my hearers against supposing that their solution should be attempted simply because they have a commercial value.

It is because they are so full of promise as scientific problems, that I think it no valid argument against their importance to theoretical science that they have been suggested in practice. In all these matters it seems to me we should recognise that practical men are doing us a service in setting questions, because they set them definitely. In the attempt to solve these problems we may be sure science will gain, and if commerce gains also, so much the better for commerce, and indirectly for us. But that is not the same thing as directly interesting ourselves

in the commercial value of the answer. This is not our function, and our advice and researches are the more valuable to commerce the less we are concerned with it.

It is clear that the magnitude of the subject referred to is far beyond the measure of our purpose to-day, and I shall restrict myself to a short review of some advances in our knowledge of the Fungi made during the last three decades.

Little more than thirty years ago we knew practically nothing of the life-history of a fungus, nothing of parasitism, of infectious diseases, or even of fermentation, and many botanical ideas now familiar to most educated persons were as yet unborn. Our knowledge of the physiology of nutrition was in its infancy, even the significance of starches and sugars in the green-plant being as yet not understood; root-hairs and their importance were hardly spoken of; words like *heterœcism, symbiosis, mycorhiza,* &c., did not exist, or the complex ideas they now connote were not evolved. When we reflect on these facts, and remember that *bacteria* were as yet merely curious 'animalculæ,' that rusts and smuts were generally supposed to be emanations of diseased states, and that 'spontaneous generation' was a hydra not yet destroyed, we obtain some notion of the condition of this subject about 1860.

As with other groups of plants, so with the Fungi, the first studies were those of collecting, naming and classifying, and prior to 1850 the few botanists who concerned themselves with these cryptogams at all were systematists. So far as the larger fungi are concerned, the classification attained a high degree of perfection from the point of view of an orderly arrangement of natural objects, and the student of to-day may well look back at the keen observation and terse, vivid descriptions of these older naturalists, which stands in sharp contrast to much of the more slovenly and hurried descriptive work which followed.

It may be remembered that even now we rely mainly on the descriptions and system of Fries (1821–1849) for our grouping of the forms alone considered as fungi by most people, and indeed we may regard him as having done for fungi what Linnæus did for flowering plants.

But, as you are aware, a large proportion of the Fungi are microscopic, and in spite of the conscientious and beautiful work of several earlier observers, among whom Corda stands pre-eminent, the classification and descriptions of the thousands of forms were rapidly bringing the subject into chaos.

The dawn of a new era in Mycology was preparing, however. A few isolated observers had already begun the study of the development of Fungi, but their work was neglected, till Persoon and Ehrenberg at the beginning of this century again brought the subject into prominence, and then came a series of discoveries destined to stimulate work in quite other directions.

The Tulasnes may be said to have brought the old period to a close and prepared the way for the new one; they combined the powers of accurate observation with a marvellous faculty of delineation, and applied the anatomical method to the study of fungi with more success than ever before. Their new departure, however, is more evident in their selection of the parasitic fungi for study, and you all know how indispensable we still find their drawings of the germinating spores of the Smuts and Rusts. It is difficult to say which of their works is the most masterly, but probably the study of the life-history of *Claviceps purpurea* deserves first place, though successive memoirs on the Uredineæ, Ustilagineæ, Peronosporeæ, Tuberaceæ, and then that magnificent work the 'Selecta Fungorum Carpologia,' cannot be forgotten.

In England, Berkeley was the man to link the period previous to 1860 with the present epoch. A systematist and observer of high power, and with a rare faculty for appreciating the labours of others, this grand old naturalist did work of unequalled value for the period, and the student who wishes to learn what was the state of mycology about this time will find it nowhere better presented than in Berkeley's works, one of which—his 'Introduction to Cryptogamic Botany'—is a classic.

Like all classifications in botany, however, that of the Fungi now took two courses: one in the hands of those who collated names and herbarium-specimens, and proposed cut and dried, but necessary and from a certain point of view very

complete systems of classification, and those who, generalising from actual cultures and observation of the living plant, proposed outline schemes, the details of which should be filled in by their successors.

No one who knows the history of botany during this century will deny that it is to the genius of De Bary that we owe the foundation of modern mycology, for it was this young Alsatian who, though profoundly influenced by the work of Von Mohl and Schleiden on the one hand, and of Unger and the Tulasnes on the other, refused to follow either the school of the phytotomists—though his laborious 'Comparative Anatomy of the Ferns and Phanerogams' shows how well equipped he was to be a leader in that direction—or that of the anatomical mycologists. No doubt the influence of Cohn, Pringsheim, and others of that new army of microscopists who were teaching the necessity of continued observation of living organisms under the microscope, can be traced in impelling De Bary to abandon the older methods, but his own unquestionable originality of thought and method came out very early in his investigations on the Lower Algæ and Fungi. If I may compare a branch of science to an arm of the sea, we may look on De Bary's influence as that of a Triton rising to a surface but little disturbed by currents and eddies. The sudden upheaval of his genius set that sea rolling in huge waves, the play of which is not yet exhausted.

The birth and flow of the new ideas, expressed in far-reaching generalisations and suggestions which are still moving, led to the revolutions in our notions of polymorphism, parasitism, and the real nature of infection and epidemics. His development of the meaning of sexuality in Fungi, his startling discovery of heterœcism, his clear exposition of symbiosis, and even his cautious and almost wondering whisper of chemotaxis were all fruitful, and although the questions of enzyme-action and fermentation were not made peculiarly his own, he saw the significance of these and many other phenomena now grown so important, and here, as elsewhere, thought clearly and boldly, and criticised fearlessly with full knowledge and justice.

I do not propose to occupy our time with even a sketch of the history of these and other ideas of this great botanist; but rather pass to the consideration of a few of the results of some of them in the hands of later workers, in schools now far developed and widely independent of one another, but all deeply indebted to the genial little man whom we so loved and revered.

The most marked feature noticed in the founding of the new schemes of classification of the Fungi was the influence of the results of pure and continuous cultures introduced by De Bary. The effect on those who followed can best be traced by examining the great systems of subsequent workers, led by Brefeld and Van Tieghem, and the writings of our modern systematists. This task is beyond my present scheme, however, and there is only time to remind you of the fungus floras of Saccardo, Constantin, Massee, and others, in this connection.

The word 'fermentation' usually recalls the ordinary processes concerned in the brewing of beer and the making of wines and spirits; but we must not forget that the word connotes all decompositions or alterations in the composition of organic substances induced by the life-activities of Fungi, and that it is a mere accident which brings alcoholic fermentation especially into prominence.

I ventured some time ago to term alcoholic fermentation the oldest form of microscopic gardening practised by man, and this seems justified by what we know of the very various and very ancient processes in this connection.

But the making of beers, wines, and spirits, as we understand them, constitutes but a small part of the province of fermentation, and even when we have added cider and perry, ginger-beer, and the various herb and spruce beers to the list, we have by no means exhausted the tale of fermented drinks. Palm-wines of various kinds, toddy, pulque, arrack, kava, and a number of tropical alcoholic fermented liquors have to be included, and the koumiss and kephir of the Caucasus, the curious Russian kwass, the Japanese saké, and allied rice-preparations must be mentioned, to say nothing of the now almost forgotten birch-beer, mead and metheglin, and various other strange fermented decoctions of our forefathers' time or confined to out-of-the-way localities.

In all these cases the same principal facts come out—a saccharine liquid is exposed to the destructive action of fungi, which decompose it, and we drink the altered or fermented liquor. As is now well known, the principal agents in these fermentations are certain lower forms of fungi called yeasts, and since Leeuwenhoeck, of Delft, discovered the yeast cells two hundred years ago, and La Tour, Schwann, and Kützing (about 1840) recognised them as budding plants, living on the sugar of the liquid, and which must be classed as Fungi, the way was paved for two totally different inquiries concerning yeast.

One of these was the fruitful one instigated by Pasteur's genius about 1860, and concerned the functions of yeast in fermentation. In the hands of Naegeli, Brefeld, and others abroad, and of A. J. and Horace Brown and Morris and others in England, Pasteur's line of research was rapidly developed, and, as we all know, has had a wide influence in stimulating investigation and in suggesting new ideas; and although the theory of alcoholic fermentation itself has not withstood all the criticism brought against it, and seems destined to receive its severest blow this year by E. Buchner's isolation of the alcoholic enzyme, we must always honour the school which nursed it.

The divergent line of inquiry turned on the origin and morphological nature of yeast. What kind of a fungus is yeast, and how many kinds or species of yeasts are there?

Reess, in 1870, showed the first steps on this long path of inquiry, and gave the name *Saccharomyces* to the fungus, showing that several species or forms existed, some of which develop definite spores.

In 1883, Hansen, of Copenhagen, taking advantage of the strict methods of culture introduced and improved by De Bary, Brefeld, Klebs, and other botanists, had shown that by cultivating yeast on solid media from a single spore it was possible to obtain constant types of pure yeasts, each with its own peculiar properties.

One consequence of Hansen's labours was that it now became possible for every brewer to work with a yeast of uniform type instead of with haphazard mixtures, in which serious disease forms might predominate and injure the beer. Another consequence soon appeared in Hansen's accurate diagnosis of the specific or varietal characters of each form of yeast, and among other things he showed that a true yeast may have a mycelial stage of development. The question of the nucleus of the yeast-cell, on which Mr. Wager will enlighten us, has also occupied much attention, as have also the details of spore formation.

Meanwhile, a question of very general theoretical interest had arisen.

Reess, Zopf, and Brefeld had shown that many higher fungi can assume a yeast-like stage of development if submerged in fluids. Various species of *Mucor, Ustilago, Exoascus,* and as we now know, numerous Ascomycetes and Basidiomycetes as well, can form budding cells, and it was natural to conclude that probably the yeasts of alcoholic fermentation are merely reduced forms of these higher fungi, which have become habituated to the budding condition—a conclusion apparently supported by Hansen's own discovery that a true *Saccharomyces* can develop a feeble but unmistakable mycelium.

With many ups and downs this question has been debated, but as yet we do not know that the yeasts of alcoholic fermentations can be developed from higher fungi.

During the last two years it appeared as if the question would be settled. Takamine stated that the *Aspergillus* used by the Japanese in brewing saké from rice develops yeast-like cells which ferment the sugar derived from the rice. Jühler and Jorgensen then extended these researches and claimed to have found yeast-cells on other forms of fungi on the surface of fruits, and to have established that they develop endogenous spores—an indispensable character in the modern definition of the genus *Saccharomyces*—and cause alcoholic fermentation.

Klöcker and Schiönning have this last year published the results of their very ingenious and thorough experimental inquiry into this question, and find, partly by pure cultures of the separate forms, and partly by means of excellently devised

cultures on ripening fruits still attached to the plant, but imprisoned in sterilised glass vessels, that the yeasts and the moulds are separate forms, not genetically connected, but merely associated in nature, as are so many other forms of yeasts, bacteria and moulds.

It is interesting to notice how here, as elsewhere, the lessons taught by pure cultures are found to bear fruit, and how Hansen's work justifies the specialist's laboratory.

Among the most astonishing results that have come to us from such researches are Hansen's discoveries that several of the yeasts furnish quite distinct races or varieties in different breweries in various parts of the world, and it seems impossible to avoid the conclusion that their race characteristics have been impressed on the cells by the continued action of the conditions of culture to which they have so long been exposed—they are, in fact, domestic races.

Much work is now being done on the action of the environment on yeasts, and several interesting results have been obtained. One of the most striking examples is the fact observed by Sauer, who found that a given variety of yeast, whose activity is normally inhibited when the alcohol attains a certain degree of concentration in the liquid, can be induced to go on fermenting until a considerably higher proportion of alcohol is formed if a certain lactic-acid bacterium is added to the fermenting liquor. The bacterium, in fact, prepares the way for the yeast. Experiments have shown that much damage may be done to beers and wines by foreign or weed germs gaining access with the yeasts, and Hansen has proved that several yeasts are inimical to the action of the required fermentation. But not all pure fermentations give the desired results: partly because the race-varieties of even the approved yeasts differ in their action, and partly, as it appears, on account of causes as yet unknown.

There are facts which lead to the suspicion that the search for the best possible variety of yeast may not yield the desired results, if this particular form is used as a pure culture. The researches of Hansen, Rothenbach, Delbrück, Van Laer, and others, suggest that associated yeasts may ferment better than any single yeast cultivated pure, and cases are cited where such a symbiotic union of two yeasts of high fermenting power has given better results than either alone.

If these statements are confirmed, they enhance the theoretical importance of some investigations I had made several years previously. English ginger-beer contains a curious symbiotic association of two organisms—a true yeast and a true bacterium—so closely united that the yeast-cells imprisoned in the gelatinous meshes of the bacterium remind one of the gonidia of a lichen entangled in the hyphæ of the fungus, except that there is no chlorophyll. Now it is a singular fact that this symbiotic union of yeast and bacterium ferments the saccharine liquid far more energetically than does either yeast or bacterium alone, and results in a different product, large quantities of lactic and carbonic acids being formed, and little or no alcohol.

In the kephir used in Europe for fermenting milk, we find another symbiotic association of a yeast and a bacterium; indeed, Freudenreich declares that four distinct organisms are here symbiotically active and necessary, a result not confirmed by my as yet incomplete investigation. I know of at least one other case which may turn out to be different from either of the above. Moreover, examples of these symbiotic fermentations are increasing in other directions.

Kosai, Yabe, and others have lately shown that in the fermentations of rice to produce saké, the rice is first acted on by an *Aspergillus*, which converts the starch into sugars, and an associated yeast—hitherto regarded as a yeast-form of the *Aspergillus*, but, as already said, now shown to be a distinct fungus symbiotically associated with it—then ferments the sugar, and other similar cases are on record.

Starting from the demonstrated fact that the constitution of the medium profoundly affects the physiological action of the fungus, there can be nothing surprising in the discovery that the fungus is more active in a medium which has been favourably altered by an associated organism, whether the latter aids the fungus by directly altering the medium, or by ridding it of products of excretion

or by adding some gas or other body. This granted, it is not difficult to see that natural selection will aid in the perpetuation of the symbiosis, and in cases like that of the ginger-beer plant it is extremely difficult to get the two organisms apart, reminding us of the similar difficulty in the case of the soredia of Lichens. Moreover, experiments show that the question of relative abundance of each constituent affects the matter.

I must now return for a moment to Buchner's discovery that by means of extremely great pressures a something can be expressed from yeast which at once decomposes sugar into alcohol and carbon-dioxide, and concerning which Dr. Green will inform us more fully. This something is regarded by Buchner as a sort of incomplete protoplasm—a body composed of proteid, and in a structural condition somewhere between that of true soluble enzymes like invertin and complete living protoplasm.

If this is true, and Buchner's *zymase* turns out to be a really soluble enzyme, the present theory of alcoholic fermentation will have to be modified, and a reversion made towards Traube's views of 1858, a reversion for which we are in a measure prepared by Miquel's proof in 1890 that *Urase*, a similar body extracted from the urea-bacteria, is the agent in the fermentation of urea. At present, however, we are not sufficiently assured that the body extracted by Buchner is really soluble, and I am told that very serious difficulties still face us as to what solution is. The enormous pressures required, and the fact that the 'solution' coagulates as a whole, might suggest that he was dealing with expressed protoplasm, still alive, but devoid of its cell-wall; against this, however, must be urged the facts that the 'solution' can be forced through porcelain and still act, and this even in the presence of chloroform.

We may fairly expect that the further investigation of Buchner's 'zymase,' Miquel's 'urase,' and the similar body obtained by E. Fischer and Lindner from *Monilia candida* will help in deciding the question as to the emulsion theory of protoplasm itself.

In any case, soluble or not, these enzymes are probably to be regarded as bits off the protoplasm, as it were, and so the essentials of the theory of fermentation remain, the immediate machinery being not that of protoplasm itself, but of something made by or broken off from it. Enzymes, or similar bodies, are now known to be very common in plants, and the suspicion that fungi do much of their work with their aid is abundantly confirmed.

Payen and Persoz discovered diastase in malt extract in 1833, and in 1836 Schwann discovered peptase in the juices of the animal stomach. Since that time several other enzymes have been found in both plants and animals, and the methods for extracting them and for estimating their actions have been much improved, a province in which Horace Brown, Green, and Vines have contributed results.

It seems not improbable that there exists a whole series of these enzymes which have the power of carrying over oxygen to other bodies, and so bringing about oxidations of a peculiar character. These curious bodies were first observed owing to studies on the changes which wine and plant juices undergo when exposed to the action of the oxygen of the air.

In the case of the wine certain changes in the colour and taste were traced to conditions which involved the assumption that some body, not a living organism, acts as an oxygen-carrier, and the activity of which could be destroyed by heating and antiseptics. It was found that similar changes in colour and taste could be artificially produced by the action of ozone, or by passing an electric current through the new wine; indeed, it is alleged that the ageing of wine can be successfully imitated by these devices, and is actually a commercial process.

The browning of cut or broken apples is now shown to be due to the action of a similar oxydase—*i.e.* an oxygen-carrying ferment, and the same is claimed for the deep-colouring of certain lacks, or lackers, obtained from the juice of plants such as the *Anacardiaceæ*, which are pale and transparent when fresh drawn, but gradually darken in colour on exposure to air. Bertrand found in these juices an oxydase, which he terms *laccase*, and which affects the oxygen-carrying, and converts the pale fluid juice to a hard dark brown varnish.

Other oxydases have been isolated from beets, *dahlia*, potato-tubers, and several other plants.

These discoveries led Bourquelot and Bertrand in 1895 to the explanation of a phenomenon long known to botanists, and partly explained by Schönbein as far back as 1868. If certain Fungi (e.g., *Boletus luridus*) are broken or bruised, the yellow or white flesh at once turns blue: the action is now traced to the presence in the cell-sap of an oxydase, the existence of which had been suspected but not proved, and the observers named assert that many fungi (59 out 107 species examined) contain such oxydases.

It will be interesting to see how far future investigations support or refute the suggestion that many of the colour-changes in diseased tissues of plants attacked by fungi are due to the action of such oxydases.

Wortmann, in 1882, showed that bacteria, which are capable of secreting diastase, can be made to desist from secreting this enzyme if a sufficient supply of sugar be given them, and since then several instances have been discovered where fungi and bacteria show changes in their enzyme actions according to the nature of their food supply. Nor is this confined to fungi. Brown and Morris, in 1892, gave evidence for the same in the seedlings of grasses: as the sugar increased, the production of diastase diminished.

It is the diastatic activity of *Aspergillus* which is utilised in the making of saké from rice in Japan, and in the preparation of soy from the soja bean in the same country, and a patented process for obtaining diastase by this means exists; and Katz has recently tested the diastatic activity of this fungus, of *Penicillium*, and of *Bacterium megatherium* in the presence of large and small quantities of sugar. All three organisms are able to produce not only diastase, but also other enzymes, and the author named has shown that as the sugar accumulates the diastase formed diminishes, whereas the accumulation of other carbohydrates produces no such effect.

Hartig's beautiful work on the destruction of timber by fungi obtains new interest from Bourquelot's discovery of an emulsion-like enzyme in many such wood-destroying forms. This enzyme splits the Glucosides, Amygdalin, Salicin, Coniferin, &c., into sugars and other bodies, and the hyphæ feed on the carbo-hydrates. I purpose to recur to this subject in a communication to this Section. The fact that *Aspergillus* can form invertins of the sucrase, maltase, and trehalase types, as well as emulsin, inulase, diastase, or trypsin, according to circumstances of nutrition, will explain why this fungus can grow on almost any organic substratum it alights on, and other examples of the same kind are now coming to hand.

The secretion of special enzymes by fungi has a peculiar interest just now, for recent investigations promise to bring us much nearer to an understanding of the phenomena of parasitism than we could hope to attain a few years ago.

De Bary long ago pointed out that when the infecting germinal tube of a fungus enters a plant-cell, two phenomena must be taken into account, the penetration of the cell-walls and tissues, and the attraction which causes the tips of the growing hypha to face and penetrate these obstacles, instead of gliding over them in the lines of apparent least resistance.

The further development of these two themes has been steady and unobtrusive, and from various quite unexpected directions more light has been obtained, so that we are now in a position to see pretty clearly what are the principal factors involved in the successful attack of a parasitic plant on its victim or 'host.' That fungi can excrete cellulose-dissolving enzymes is now well known, and that they can produce enzymes which destroy lignin must be inferred from the solution of wood-cells and other lignified elements by tree-destroying fungi. Zopf has collected several examples of fungi which consume fats, and further cases are cited by Schmidt, by Ritthausen, and Baumann. In these cases also there can be no doubt that an enzyme or similar body is concerned.

There is one connection in which recent observations on enzymes in the plant-cell promise to be of importance in explaining the remarkable destructive action of certain rays of the solar-light on bacteria. As you are aware, the English

observers Downes and Blunt showed long ago that if bacteria in a nutrient liquid are exposed to sunlight, they are rapidly killed. Further researches, in which I have had some part, gradually brought out the facts that it is really the light rays and not high temperatures which exert this bactericidal action, and by means of a powerful spectrum and apparatus furnished by the kindness of Professor Oliver Lodge I was able to obtain conclusive proof that it is especially the blue-violet and ultra-violet rays which are most effective. This proof depended on the production of actual photographs in bacteria of the spectrum itself. Apart from this, I had also demonstrated that just such spores as those of anthrax, at the same time pathogenic and highly resistent to heat, succumb readily to the action of these cold light-rays, and that under conditions which preclude their being poisoned by a liquid bathing them.

The work of Brown and Morris on the daily variations of diastatic enzyme in living leaves, and especially Green's recent work on the destructive action of light on this enzyme, point to the probability that it is the destruction of the enzymes with which the bacterial cells abound which brings about the death of the cell.

That these matters are of importance in limiting the life of bacteria in our streets and rivers, and that the sun is our most powerful scavenger, has been shown by others as well as myself. In this connection may also be mentioned Martinand's observations, that the yeasts necessary for wine-making are deficient in numbers and power on grapes exposed to intense light, and he explains the better results in Central France as contrasted with those in the South as largely due to this fact. Whether, or how far, the curious effects of too intense illumination in high latitudes and altitudes on plants which might be expected to grow normally there, can be explained by a destructive light action on the enzyme of the leaves, has not, so far as I know, been tested; but Green's experiments certainly seem to me to point to the possibility of this, as do the previous experiments with screens of Pick, Johow, myself, and others.

It is interesting to note that Wittlin and others have confirmed the conclusion my own few trials with Röntgen rays led to; they show no action whatever.

That branch of mycology which is now looked upon by so many as a separate department of science, usually termed bacteriology, only took shape in the years 1875–79, when its founder, the veteran botanist Cohn, who recognised that the protoplasm of plants corresponded to the animal sarcode, and who has been recently honoured by our Royal Society, published his exact studies of these minute organisms, and prepared the way for the specialists who followed.

It is quite true that isolated studies and observations on bacteria had been made from time to time by earlier workers than Cohn, though it is usually overlooked that Cohn's first paper on Bacteria was published in 1853. Ehrenberg in particular had paid special attention to some forms; but neither he nor his successors can be regarded as having founded a school as Cohn did, and this botanist may fitly be looked upon as the father of bacteriology, the branch of mycology which has since obtained so much diversity.

It should not be overlooked that the first proof that a specific disease of the higher animals is due to a bacillus, contained in Koch's paper on Anthrax, was published under Cohn's auspices and in his 'Beiträge zur Biologie der Pflanzen' in 1876, four years after Schroeter's work from the same laboratory on pigmented bacteria, and that the plate illustrating Koch's paper was in part drawn by Cohn.

It is of primary importance to recognise this detail of Koch's training under Cohn, because, as I have shown at length elsewhere, popular misapprehensions as to what bacteriology really consists in have been due to the gradual specialisation into three or four different schools or camps of a study which is primarily a branch of botany; and, again, it is of importance to observe that the whole of this particular branch of mycology, to which special laboratories and an enormous literature are now devoted, has arisen during the last quarter of a century, and subsequent to the foundation of scientific mycology by De Bary. When we reflect that the nature of parasitic fungi, the actual demonstration of infection by a fungus spore, the transmission of germs by water and air, the meaning and significance of polymorphism, heterœcism, symbiosis, had already been rendered clear in the case of

fungi, and that it was by these and studies in fermentation and in the life-history of the fungus *Saccharomyces* that the way was prepared for the ætiology of bacterial diseases in animals, there should be no doubt as to the mutual bearings of these matters.

Curiously enough, it was an accident which deflected bacteriology along lines which have proved so significant for the study of this particular group of minute organisms, that an uninitiated visitor to a modern bacteriological laboratory (which in England, at any rate, is usually attached to the pathological department of a medical school) hardly perceives that he is in a place where the culture of microscopic plants is the chief object—for the primary occupation of a bacteriologist is really, after all, the cultivation of minute organisms by the method of 'microscopic gardening,' invented by De Bary, Klebs, and Brefeld, whether the medium of culture is a nutritive solution, or solid organic substrata like potato, agar, or gelatine, or the tissues of an animal.

This accident—I use the word in no disrespectful sense—was Koch's ingenious modification of the use of gelatine as a medium in which to grow bacteria: he hit upon the method of pouring melted gelatine containing distributed germs on to plates, and thus isolating the colonies.

Pasteur and Cohn had already coped with the difficulty of isolating mixed forms by growing them in special fluids. When a given fluid favoured one form particularly, a small quantity containing this predominant species was put into another flask of the fluid, then a drop from this flask transferred to a third flask, and so on, until the last flasks contained only the successful species, the others having been suppressed: these 'fractional cultures' were brought to a high state of perfection by the botanist Klebs in 1873.

Then Brefeld (1872) introduced the method of dilution—*i.e.*, he diluted the liquid containing his spores until each single drop taken contained on the average one spore or none, whence each flask of sterile nutritive solution receiving one drop contained either none or *one* spore. Brefeld was working with fungi, but Lister—now Lord Lister, and our late President—applied this 'dilution method' to his studies of the lactic fermentation in 1878, and Naegeli, Miquel, and Duclaux carried it further, the two latter especially having been its chief defenders, and Miquel having employed it up to quite recently.

Solid media appear to have been first generally used by Schroeter in 1870, when he employed potatoes, cooked and raw, egg-albumen, starch-paste, flesh, &c. Gelatine, which seems to have been first employed by Vittadini in 1852, was certainly used by Brefeld as early as 1874, and even to-day his admirable lecture on *Methoden zur Untersuchung der Pilze* of that date is well worth reading, if only to see how cleverly he obtains a single spore isolated in gelatine under the microscope. Klebs used gelatine methods in 1873.

We thus see that when Koch proposed his method of preparing gelatine plate-cultures in 1881 he instituted, not a new culture-medium, for cultures on solid media, including gelatine, had been in use by botanists for eight or ten years; nor did he introduce methods for the isolation of spores, for this had been done long before. What he really did was to ensure the isolation of the spores and colonies wholesale, and so facilitate the preparation of pure cultures on a large scale, and with great saving of time.

It was a brilliant idea, and, as has been said, 'the Columbus egg of Bacteriology;' but we must not lose sight of the fact that it turned the current of investigation of bacteria from the solid and reliable ground established by Cohn, Brefeld, and De Bary, into a totally new channel, as yet untried.

We must remember that De Bary and Brefeld had aimed at obtaining a single spore, isolated under the microscope, and tracing its behaviour from germination, continuously to the production of spores again; and when we learn how serious were the errors into which the earlier investigators of the mould-fungi and yeasts fell, owing to their failure to trace the development continuously from spore to spore, and the triumphs obtained afterwards by the methods of pure cultures, it is not difficult to see how inconclusive and dangerous all inferences as to the morphology of such minute organisms as bacteria must be unless the plant has been so observed.

As matter of fact, the introduction and gradual specialisation of Koch's methods of rapid isolation of colonies encouraged the very dangers they were primarily intended to avoid. It was soon discovered that pure cultures could be obtained so readily that the characteristic differences of the colonies in the mass could presumably be made use of for diagnostic purposes, and a school of bacteriologists arose who no longer thought it necessary to patiently follow the behaviour of the single spore or bacillus under the microscope, but regarded it as sufficient to describe the form, colour, markings, and physiological changes of the bacterial colonies themselves on and in different media, and were content to remove specimens occasionally, dry and stain them, and describe their forms and sizes as they appeared under these conditions.

To the botanist, and from the points of view of scientific morphology, this mode of procedure may be compared to what would happen if we were to frame our notions of species of oak or beech according to their behaviour in pure forests, or of a grass or clover according to the appearance of the fields and prairies composed more or less entirely of it, or—and this is a more apt comparison, because we can obtain colonies as pure as those of the bacteriologist—of a mould-fungus according to the shape, size, and colour, &c., of the patches which grow on bread, jam, gelatine, and so forth.

Now it is obvious that this is abandoning the methods of morphology, and the consequence has been that two schools of descriptive bacteriologists are working along different lines, and the 'species' of the one—the test-tube school—cannot be compared with those of the other, the advocates of continuous culture from the spore.

The difficulty of isolating a bacterium and tracing its whole life-history under the microscope is so great, that the happy pioneers into the fascinating region opened up by the test-tube methods may certainly claim considerable sympathy in their cry that they cannot wait. Of course they cannot wait; no amount of argument will prevent the continual description of new test-tube 'species,' and all we can do is to go on building up the edifice already founded by the botanists Cohn, Brefeld, De Bary, Van Tieghem, Zopf, Prazmowski, Beyerinck, Fischer, and others who have made special studies of bacteria.

The objection that such work is slow and difficult has no more weight here than in any other department of science, and in any case the test-tube school is already in the plight of being frequently unable to recognise its own 'species,' as I have convinced myself by a long-continued series of cultures with the object of naming common bacteria.

I wish to guard myself against misconstruction in one particular here. It is not insinuated that the test-tube methods and results are of no value. Far from it; a vast amount of preliminary information is obtained by it; but I would insist upon the discouragement of all attempts to make 'species' without microscopic culture; and continuous observation of the development as far as it can be traced.

The close connection between bacteriology and medicine has been mainly responsible for the present condition of affairs; but it is high time we recognised that bacteriology only touches animal pathology at a few points, and that the public learn that, so far from bacteria being synonymous with disease germs, the majority of these organisms appear to be beneficial rather than inimical to man. There is not time to attempt even a brief description of all the 'useful fermentations' due to bacteria, but the following cases will point the conviction that a school of bacteriology, which has nothing to do with medical questions, but investigates problems raised by the forester, agriculturist, and gardener, the dairyman, brewer, dyer, and tanner, &c., will yet be established in England in connection with one or other of our great botanical centres.

There are many industrial processes which depend more or less for their success on bacterial fermentations. The subject is young, but the little that has been discovered makes it imperative that we should go on, for not only are the results of immense importance to science, but they open up vistas of practical application, which are already being taken advantage of in commerce, and we may be sure that every economic application of such knowledge will give the people employing it an

advantage over those who proceed by the old rule-of-thumb methods, where nobody knows or cares where the waste or leakage occurs that spoils a commercial product.

The discovery by Alvarez of the bacillus which converts a sterilised decoction of indigo-plant into indigo sugar and indigo white, the latter then oxidising to form the valuable blue dye, whereas the sterile decoction itself, even in presence of oxygen, forms no indigo, may be cited as a case in point. It remains to be decided whether this bacillus alone is concerned, or whether the infusion of indican will ferment under the action of enzymes alone derived from the leaves of the indigo plant. It also remains for future investigation to determine whether the indigo bacillus is the same as the pneumonia bacillus—which resembles it—and will also induce the indigo fermentation, and to explain why the woad-makers of the Fens find a sale for this indigo preparation among the indigo makers, as well as to clear up certain mysterious 'diseases' in the indigo-vats. Our much more extensive knowledge of the diseases of beer and wine suggests the possibility of profitable bacteriological investigations in several directions here.

That certain stages in the preparation of tobacco leaves—as also in the preparation of tea—depend on a carefully regulated fermentation, which must be stopped at the right moment, or the product is impaired, or even ruined, has long been known. Regarding the possible *rôle* of bacteria in the preparation of tea, nothing is ascertained, but, if Suchsland's investigations are confirmed, there is among the many and various organisms concerned in the fermentation of West Indian tobacco a bacterium which has been isolated and plays an important part. It is claimed that the flavour of European-grown tobacco can be materially improved by its use. I read that the process is patented, which may or may not affect its value as a scientific announcement; but in view of the increasing number of researches into this subject by Behrens, Dávalos, Schloesing, and others, it is evidently a domain for further bacteriological investigations in a properly equipped laboratory.

Every botanist knows that flax and hemp are the bast fibres of *Linum* and *Cannabis* respectively, separated by steeping in water until the middle lamella is destroyed and the fibres isolated; but it is perhaps not so well known that not every water is suitable for this 'retting' or steeping process, and for a long time this was as much a mystery as why some waters are better than others for brewing.

Only quite recently Fribes, working under Winogradsky, has isolated the bacillus which accomplishes this dissolution of the middle lamella, and its behaviour brings to light some very interesting details, and furnishes another of those cases where the reactions of living micro-organisms can be utilised in deciding questions of plant chemistry too subtle for testing with ordinary reagents.

You are aware that recent researches, especially those of Maquin in France and of Walter Gardiner in Cambridge, Cross and Bevan and others, have caused us to discard the view that the middle lamella is composed of cellulose, and to learn that it consists of pectin compounds. Now Fribes' anaërobic bacillus dissolves and destroys pectins and pectinates, but does not touch cellulose or gum, and thus enables us to criticise from a new point of view the bacillus (*B. Amylobacter*) which Van Tieghem asserted to be the cause of cellulose fermentation and of the retting of flax. Clearly it cannot be both, otherwise the flax-fibre would be destroyed; and we know from other facts that *B. Amylobacter* is not the cellulose ferment.

Fribes' discovery has yet to be tested with reference to other processes of retting. The Indian Government have lately published a series of notes on jute and other fibres, and the description of the retting of jute suggests this as a very definite problem for investigation.

I am told that a patent exists in the United States for a process whereby the retting organisms may be sown and encouraged in waters otherwise unfitted for the steeping of flax, &c., another indication of the keen interest taken in these matters.

It goes without saying that the steeping of skins in water in preparation for

tanning involves bacterial actions, owing to which the hair and epidermal coverings are removed; but it appears from recent investigations that in the process of swelling the limed skins, the gases evolved in the substance of the tissues, and the evolution of which causes the swelling and loosens the fibre so that the tanning solutions may penetrate, are due to a particular fermentation, caused by a bacterium which, according to Wood and Wilcox, is similar to, if not identical with, a lactic ferment. If Haenlein's results may be accepted, it is a bacillus introduced into the tanning solution by the pine bark, which is responsible for the advantageous acidification of the tanning solutions much valued for making certain kinds of leather, and of decisive importance in the quality, so that tanners add the souring liquor of other vats to encourage the souring of the doubtful one.

Hay is made in very different ways in different countries, and in those where a 'spontaneous' heating process is resorted to there seems to be no doubt that certain thermogenic bacteria are concerned. The researches of Böhmer, Dietrich, Fry, Lafar, and others show that here and in the preparation of ensilage we have important fermentation processes which affect the end result.

The whole question of fermentation in hay, and the high temperatures produced in the process, as well as what occurs in straw-stacks under similar conditions, have important theoretical bearings, and we know of bacilli which grow at 70° C.

Probably no other subject in this domain has, however, attained so much importance as the bacteriology of the dairy—the study of the bacteria found in milk, butter, and cheese in their various forms. In all cases of this kind, as in brewing, bread-making, and so on, there are three aspects of the bacteriology of the operations: we have to consider first the bacteria concerned in the normal process; secondly, introduced forms which bring about abnormalities, or 'diseases' of the normal operation; and, thirdly, the possible pathogenic bacteria, *i.e.*, pathogenic to man, which may lurk in the product.

Of milk especially much has been said as a disease-transmitting medium, and with good reason, as is well known; and if we may accept the statement of a Continental authority, who calculated that each time we eat a slice of bread and butter we devour a number of bacteria equal to the population of Europe, we have grounds for demanding information as to what these bacteria are, and what they are doing. And similarly with cheese, every kind of which teems with millions of these minute organisms.

Now I cannot, of course, go into the question of pathogenic bacteria, nor is there time to discuss those forms which bring about undesirable or abnormal processes in the dairy; but I want to call your attention to the splendid field for bacteriological investigation which is being opened up by inquiries into the normal changes utilised in making butter and cheese.

We may pass over the old controversies as to the souring of milk, culminating in Pasteur's discovery of the bacteria of lactic fermentation in 1857–58. Lister in 1877 isolated *Bacterium lactis*. Hueppe in 1884 confirmed his results, and added several other lactic bacteria, and we now know a whole series of forms which can turn milk sour by fermenting its sugar, and this in various ways, as Warington and others have shown. The souring of milk and cream by merely leaving it to stand often led to failure, and the study of this preliminary to butter- and cheese-making is itself a bacteriological question of great importance. We shall not be surprised, therefore, that when, in 1890, Wiegmann proposed to use pure cultures of lactic-acid bacteria for the souring of cream, the plan was at once taken up.

Some years ago Storch found that the peculiar aroma of a good butter was due to a bacterium which he isolated, and Wiegmann has now two forms, or races, one of which develops an exquisite flavour and aroma, but the butter keeps badly, while the other develops less aroma, while the butter keeps better.

According to a recent publication of Conn's, however, this subject has been advanced considerably in America, for they have isolated and distributed to numerous dairies pure cultures of a particular butter-bacillus which develops the famous 'June flavour' hitherto only met with in the butter of certain districts during a short season of the year. I am told that this fine-flavoured butter is now prepared constantly in a hundred or more American dairies. Simultaneously with

these advances in the manufacture of pure butter with constant flavour, the days of 'diseased' butters seem numbered.

Properly considered, the manufacture of cheese is a form of microscopic gardening even more complex and more horticultural in nature than the brewing of beer. From the outset, when the cheesemaker guards and cools his milk till his stock is ready, he is doing all he knows how to do to keep down the growth of the germs introduced into the milk; he then coagulates it, usually with rennet—an enzyme of animals, but also common in plants—and the curd thus prepared is simply treated as a medium on which he grows certain fungi and bacteria, with the needful precautions for favouring their development, protecting them against the inroads of animal and plant pests, and against unsuitable temperature, moisture, access of light, and so on. Having succeeded in growing the right plants on his curd, his art then demands that he shall stop their growth at the critical period, and his cheese is ready for market.

The investigations of Duclaux, Wiegmann, and others on the Continent, of Conn in America, and of Lloyd in England, to say nothing of other workers now busy at this subject in various parts of the world, are getting at the particular forms of fungi concerned in so altering the constitution of curd that it becomes the very different article of food we call cheese, and they have even determined to some extent what *rôle* is played by these plants in giving the peculiar odours and flavours to such different cheeses as Camembert, Stilton, and Roquefort. It is known, for instance, that a certain fungus (*Penicillium*) cultivated on bread is purposely added to Roquefort, and that it destroys the lactic and other acids and so enables certain bacteria in the cheese, hitherto inhibited in their actions by these acids, to set to work and further change the medium, whereas in making Emmenthaler cheese the object is to prevent this fungus thus paving the way for these bacteria. Pammel claims to have discovered a bacillus which gives a peculiar and much-admired clover aroma to certain cheeses, and according to recent statements a definite *Streptococcus* is responsible for the peculiarities of certain Dutch cheeses, and so on. Nevertheless, we are still profoundly ignorant of most of the forms concerned in the ripening of cheese, and every research which throws light on this difficult and complex subject, and so paves the way to rendering uniform and certain this at present most haphazard and risky manufacture will be doing service to the State. Considering that Cohn only discovered that the ripening process is due to bacteria in 1875, and that Duclaux only published his researches on *Tyrothrix* in 1878, we can scarcely be surprised that the interval has not been long enough for the isolation and study of the numerous and curious forms, several hundreds of which are now imperfectly known. Nevertheless, there are signs of advance in various directions, and researches into the mysteries of Roquefort, Gorgonzola, Emmenthaler, and other cheeses are being industriously pursued on the Continent. Even as I write this comes the news that Freudenreich has discovered the coccus which causes the ripening of Emmenthaler cheese. It is not impossible that the much more definite results obtained by investigations into the manufacture of the vegetable cheeses of China and Japan will aid bacteriologists in their extremely complex task.

These vegetable cheeses are made by exposing the beans of the leguminous plant *Glycine*—termed soja-beans—to bacterial fermentations in warm cellars, either after preliminary decomposition by certain mould-fungi, or without this. The processes vary considerably, and several different kinds of bean-cheeses are made, and known by special names. They all depend on the peculiar decompositions of the tissues of the cotyledons of the soja-bean, which contain 35 to 40 per cent. of proteids and large quantities of fats. The softened beans are first rendered mouldy, and the interpenetrating hyphæ render the contents accessible to certain bacteria, which peptonise and otherwise alter them.

Here, however, I must bring this subject to a close, and time will not permit of more than the mere mention of the vinegar fermentation, to which Mr. Adrian Brown has lately contributed valuable knowledge, of the preparation of soy, a brine extract of mouldy and fermented soja-beans, of bread-making, and other equally interesting cases.

When the idea of parasitism was once rendered definite, as it was by De Bary's work, and the fundamental distinction between a parasite and a saprophyte had been made clear, it soon became evident that some distinction must be made between *obligate facultative parasites* and *saprophytes* respectively; but when De Bary proposed the adoption of these terms of Van Tieghem's he can hardly have contemplated that they would be abused as they have been, and was clearly alive to the existence of transitions which we now know to be so numerous and so gradual in character that we can no longer define any such physiological groups.

Twenty years ago *Penicillium* and *Mucor* would have been regarded as saprophytes of the most obligate type, but we now know that under certain circumstances these fungi can become parasites; and the border-land between facultative parasites and saprophytes on the one hand and between the former and true parasites on the other can no longer be recognised.

In 1866 the germ of an idea was sown which has taken deep root and extended very widely. De Bary pointed out that in the case of lichens we have either a fungus parasite on an alga, or certain organisms hitherto accepted as algæ are merely incomplete forms. In 1868 Schwedendener declared the lichen to be a compound organism.

In 1879, in his celebrated lecture, De Bary definitely launched the new hypothesis, and brought together the facts which warranted his disturbance of the serenity of those unprepared to accept so startling a new notion as *Symbiosis.*

The word itself, in the form 'Symbiotismus,' is due to Frank, who, in an admirable paper on the biology of the thallus of certain lichens, very clearly set forth the existence of various stages of life in common.

This paper has been too much overlooked; but its existence is the more noteworthy from its being in the same number of the 'Beiträge zur Biologie'—which we owe to Cohn, the founder of scientific bacteriology—in which Koch's remarkable paper on Anthrax occurs.

The details of these matters are now principally of historical interest; we now know that lichens are dual organisms, composed of various algæ, symbiotic with ascomycetes and even basidiomycetes, and, as Massee has shown, even gastromycetes. The soil contains also bacterio-lichens. The point for our consideration is rather that botanists were now awakened to a new biological idea—viz., that a fungus may be in such nicely balanced relationships with the host from which it derives its supplies as to afford some advantage in return, whence we must look upon the limited liability company formed by the two symbionts as a better business concern than either of the plants could establish for itself—a case, in fact, where union is strength. Symbiosis, consequently, is now understood to be of advantage to both the symbionts, and not to one only, as is the case in parasitism, or, to use Vuillemin's term, *Antibiosis.*

In 1841 an English botanist, Edwin Lees, discovered the existence of 'a hirsuture that appears like a byssoid fungus' on the roots of *Monotropa,* and observed that the hyphæ linked the roots to those of a beech; he regarded the fungus as conveying nutriment from the latter to the former, and as an essential constituent of the *Monotropa.* This discovery was published in the now defunct 'Phytologist' for December 1841, and was unearthed by Oliver and by Dr. Dyer, of Kew. This is apparently the first observation of a mycorhiza yet recorded, and, although the naturalists referred to did not understand the full significance of Lees' find, several of them made excellent guesses as to the meaning of the phenomenon. As Dr. Dyer points out, it disposes of Wahrlich's claim that Schleiden (1842) first discovered mycorhiza, as well as of Woronin's contention that the priority is due to Kamienski, though the latter (1881–82) probably was the first to clearly indicate that we have here a case of symbiosis, and thus anticipated Frank's generalisation in 1885.

Kamienski and Frank, followed by numerous other observers, among whom Oliver and Groom are to be mentioned, have now shown that the peculiar type of symbiosis expressed in this intimate union of fungus-hyphæ with the living cells of the roots of trees and other plants in soils which abound in vegetable remains—*e.g.*, leaf-mould, moors, &c.—is very common.

In the humus of forests we find the roots of beeches and other *Cupuliferæ*, willows, pines, and so forth, clothed with a dense mantle of hyphæ and swollen into coral-like masses of mycorhiza; in similar soils, and in moorlands which abound in the slowly decomposing root-fibres and other vegetable remains so characteristic of these soils, the roots of orchids, heaths, gentians, &c., are similarly provided with fungi, the hyphæ of which penetrate further into the tissues, and even send haustoria into the living cells, but without injuring them.

As observations multiplied it became clear that the mycorhiza, or fungus-root, was not to be dismissed as a mere case of roots affected by parasites, but that a symbiotic union, comparable to that of the lichens, exists; and that we must assume that both the tree and the fungus derive some benefit from the connection.

Pfeffer, in 1877, suggested that the deficiency of root-hairs observed in orchids might be explained by the fungus-hyphæ playing the part of these organs, and taking up materials from the soil which they then handed on to the roots. He is quite clear on the subject, and recognises the symbiosis definitely, comparing it with other cases of symbiosis indicated by De Bary.

Frank stated that, as the results of experiments, seedling forest-trees cannot be grown in sterilised soil, where their roots are prevented from forming mycorhiza, and concluded that the fungus conveys to the roots organic materials, which it obtains by breaking down the leaf-mould and decaying plant-remains, together with water and minerals from the soil, and plays especially the part of a nitrogen-catching apparatus. In return for this important service the root pays a tax to the fungus by sparing it certain of its tissue contents, and no doubt can well afford to do so.

It appears that the mycorhiza is only formed where humus or vegetable-mould abounds. In sandy soils the roots bear root-hairs, as usual, and it is now clear that, while mycorhiza is a far more general phenomenon than was previously supposed, it is not essential for all the roots, nor even under all circumstances for any of them.

Probably what really happens is this. Trees and other plants with normal roots and root-hairs, when growing in ordinary soil, can adapt their roots to life in a soil heavily charged with humus only by contracting the symbiotic association with the fungus and paying the tax demanded by the latter in return for its supplies and services. If this adaptation is impossible, and no other suitable variation is evolved, such trees cannot grow in such soils.

In certain cases—*e.g.*, ground orchids, *Monotropa*, various *Ericaceæ*, &c.—it would seem that the plant is unable to grow in other than humus soils, and always forms mycorhiza.

Much further we cannot at present go, but it is evident that various different grades of symbiosis exist in these mycorhizas. In the first place, there are several different fungi concerned—those on cupuliferæ and pines, apparently mostly *Tuberaceæ* and *Gasteromycetes*, and allied forms, being different from those in orchids, some at least of which appear to be *Nectrias* or related genera.

The physiological relations of the root to the fungus must be different in details in the case of non-green, purely saprophytic plants, like *Neottia*, *Monotropa*, &c., and in that of the green plants like *Erica*, *Fagus*, *Pinus*, &c.

It is well known that ordinary green plants cannot utilise vegetable *débris* directly, whereas trees in forests appear to do so; this in appearance only, however, for the fungi, yeasts, and bacteria there abounding are actively decomposing the leaves and other remains.

Now it is possible that the mycorhiza theory is not applicable in all cases, and that, sometimes, what happens is this. The trees, once well established, make so good a fight that in spite of the leaf-decomposing fungi attacking their roots parasitically, or merely ensconcing themselves in the dead primary cortex as it is sloughed, they manage to keep going and to obtain such shares of the nitrates and other products due to the fungus-action as satisfy their needs. But although there may be something to be said for this view as regards a few forest-trees, it is not easy to see how it would apply to the non-assimilating humus-plants like *Neottia*, *Monotropa*, &c., and we may probably regard the two sets of cases as standing or falling together.

No treatment of this subject would be complete without reference to those obscure cases of symbiosis—as we must regard them—between certain algæ which occur in the cavities of the leaves of *Azolla* and in *Gunnera,* and those found in the intercellular spaces of cycad-roots. When we know more of the physiology of these blue-green algæ, it may be possible to explain these puzzles, but at present they are mysterious curiosities.

A class of pseudo-symbiotic organisms is being more and more brought into the foreground where the combined action of two symbionts results in death or injury to a third plant, whereas each symbiont alone is harmless, or comparatively so.

Some time ago Vuillemin showed that a disease in olives results from the invasion of a bacillus (*B. oleæ*), which, however, can only obtain its way in the tissues through the passages driven by the hyphæ of a fungus (*Chætophoma*). The resulting injury is a sort of burr. Vuillemin has this year observed the same bacillus and fungus in the canker burrs of the ash, and so confirms Noack's statement to the same effect.

Among many similar cases, well worth further attention, the invasion of potato-tubers by bacteria, which make their way down the decaying hyphæ of pioneer fungi, may be noted. I have also seen tomatoes infected by these means, and have facts showing that many bacteria which quicken the rotting of wood are thus led into the tissues by fungi.

Probably no subject in the whole domain of cryptogamic botany has wider bearings on agricultural science than the study of the flora and changes on and in manure and soil.

As vegetable physiology and agricultural science progressed, it became more and more of primary importance that we should learn what manure is composed of, what changes it undergoes in the soil, and what the roots of plants do with it. Chemistry did much to solve some of the earlier problems, but it soon became evident that it only raised new questions which it could not solve; and it was not till the sequence of changes induced by the successive growths of *Mucor, Pilobolus, Coprinus, Ascobolus,* and other moulds and fungi of various sorts, followed by bacteria and yeasts, began to be understood, that anything approaching a coherent account of the complex phenomena going on in soil or in a manure-heap could be attempted. Not that all the difficulties have been solved even now, but we are at least able to trace some very important chains of occurrences which throw light on many hitherto obscure matters going on in the field.

Since Pasteur in 1862, and Van Tieghem in 1864, showed that certain bacteria are concerned in converting urea to ammonium carbonate, much has been learnt, and we now know from the investigations of Miquel, Jaksch, Leube, and others that numerous urea-bacteria exist; and Miquel, in 1890, isolated an extremely unstable enzyme—urase—which converts sterile urea to ammonium carbonate very rapidly, a discovery of considerable interest, as it was one of the first examples of this class of bodies to be examined; and when we reflect on the enormous quantities of urea which have to be destroyed daily, and that fresh urine is in effect a poison to the roots of higher plants, some idea of the importance of these urea-bacteria is obtained. The necessity for preventing the losses of this volatile ammonia by fixing it in the soil and presenting it to the action of the nitrifying organisms is also obvious.

Winogradsky's classical isolation and cultivation of bacteria which take up these ammonia compounds and oxidise them to nitrous and to nitric acids in the soil, may be quoted as further instances of the bearing of bacteriological work on this department of science, as explaining not only the origin of nitre-beds and deposits, but also the way the ammonia compounds fixed by the soil in the neighbourhood of the root-hairs are nitrified and so rendered directly available to plants.

The theoretical explanation of many questions connected with the washing out of nitrates from fallows, the advantages of autumn and winter sowing, and processes occurring in the upper soil as contrasted with subsoil, has been rendered much easier by these researches; moreover, as is now well known, they brought

to our knowledge a startling instance of the assimilation of carbon-dioxide by these non-green plants—bacteria—which not only take some of the purely inorganic ammonia, but by means of energy set free by its oxidation obtain their carbon also by breaking up the carbonate—a true case of the assimilation of carbon-dioxide by a plant devoid of chlorophyll and without the direct aid of light. Indirectly, it is true, the source of the energy is the light of the sun, because the oxygen employed by these aërobic forms has been liberated by green plants in the last instance; but the case is none the less a startling and important contribution to physiology, and Winogradsky's work, which had been preceded by investigations in England by Warington and others, affords one of the best illustrations I know of the importance of this branch of botanical investigation.

Stutzer and Hartleb's recent publications go to show that the nitrifying organism is a much more highly developed and complex form than has hitherto been suspected; that it can be grown on various media, and exhibits considerable polymorphism—for instance, it can be made to branch, and show the characteristics of a true fungus, statements confirmed to a certain extent and independently by the even more recent work of Rullmann; and it appears that we have much more to learn of the morphology of this widely spread and interesting plant.

It is impossible to go into the controversy between the observers referred to and Winogradsky, the discoverer of the definite nitrifying organism; but there is one point I must just mention: if Stutzer and Hartleb's details are confirmed we have here the most remarkable case of polymorphism I know of, for they claim characters for their fungus which prevent our putting it into any existing group.

I have for some time insisted on the fact that river-water contains reduced forms of bacteria—*i.e.*, forms so starved and so altered by exposure to light, changes of temperature, and the low nutritive value of the river-water, that it is only after prolonged culture in richer food-media under constant conditions that their true nature becomes apparent. Now, Stutzer and Hartleb show that the morphological form of this nitrifying organism can be profoundly altered by just such variations in the conditions as the above, and occurs as a branched mycelial form, as bacilli or bacteria, or as cocci of various dimensions according to conditions.

These observations, and the researches of Zopf, Klebs, and others on variations in form (polymorphism) in other fungi and bacteria, open out a vast field for further work, and must lead to advancements in our knowledge of these puzzling organisms; they also help us to explain many inconsistencies in the existing systems of classification of the so-called 'species' of bacteria as determined by test-tube cultures.

But the urea bacteria and the nitrifying organisms are by no means the only forms found in manure and soils.

In 1868 Reiset found evidence of a reduction of nitrates in fermenting beet-juices, and in 1873 Schloesing found that free nitrogen escaped in certain soil-fermentations. Further work by Mensel, Deherain, and others led to the suspicion that certain bacteria can undo the work of the nitrifying organisms, and in 1879 Warington showed that both nitrites and nitrates occurred in his soil-fermentations.

In 1886 Gayon and Dupetit put this almost beyond doubt, and in 1891 Giltay and Aberson isolated and cultivated a denitrifying bacterium, capable of completely reducing nitrates with evolution of free nitrogen, provided it is cultivated anaërobically. Several such forms have now been obtained, the observations of Burri and Stutzer that certain of the commonest bacteria of the alimentary canal —e.g., *B. coli commune*—abounding in fresh manure, are especially active, being particularly suggestive. You will thus notice that we have now a sketch of the whole of the down-grade part of the cycle of organic nitrogen in Nature: it only needs supplementing by the history of the fixation of free nitrogen from the atmosphere by leguminous plants and certain soil-organisms to complete the sketch.

As is well known from investigations in which Eriksson, Woronin, Frank, Prazmowski, and others, including myself, have taken part, the nodules on the roots of leguminous plants contain a fungus—the morphological nature of which is in dispute—living in symbiotic union with the protoplasm of the cells. Hellriegel

and Wilfarth showed in 1888–90 that, provided the root-nodules are present, these leguminous plants fix the free nitrogen of the atmosphere; and Laurent and Schloesing put this beyond all doubt in 1892 by demonstrating that a closed atmosphere in which *Leguminosæ* grow loses nitrogen in proportion as the plants gain it. Meanwhile Schulz Lupitz had shown that agricultural land poor in nitrogen can be made to accumulate it in paying quantities by growing lupines on it, and quite recently pure cultures of the organism of the nodules have been placed on the market under the unfortunate name *Nitragin.* It is claimed that these organisms can be readily used in practice to inoculate the seeds or soil.

Kossowitsch in 1894 showed that certain symbiotic unions of algæ with bacteria are also capable of fixing nitrogen; and Winogradsky declares that there exists in the soil a bacterium which, provided it is kept protected from oxygen by aërobic soil organisms, can itself do this. We are quite unaware of the mechanisms here concerned; but in all cases it appears certain that active destruction of carbohydrates is an essential condition, and we can only assume that the nitrogen is forced into synthetic union by means of energy derived from this destruction. Here, then, we have a glimpse of the up-grade part of the cycle of nitrogen in Nature, the importance of which to agriculture cannot be overrated. As to the theoretical bearings of the matter, we are still much in the dark, and can only anxiously await the results of further investigations into the nature of the peculiar fermentations and their products going on in these nodules. I now want to draw your attention to a bearing of the above discoveries concerning denitrifying bacteria on some agricultural and horticultural questions.

It is well known that a gardener eschews the use of fresh manure. Why is this? The most obvious reply might seem to be, because the ammonia compounds and other nitrogenous constituents in such manure are not directly useful, or are even harmful to the roots of the plants. Some recent researches suggest that the matter is more complex than this.

It has not unfrequently happened that a farmer, finding himself short of stable-manure, has made up the deficit by adding some such artificial manure as Chili saltpetre, his argument running somewhat as follows:—Both are good nitrogenous manures, the one acting slowly, the other rapidly, so that a mixture of both should be better than either alone. The results have disappointed him, and numerous experiments in Norfolk, as I am informed by Mr. Wood, and in the North of England, as Dr. Somerville assures me, have shown that most disastrous results ensue if such mixtures are used, whereas if the farmyard manure is employed at first—the 'shorter' the better—and the nitrates applied later on as a 'top-dressing,' excellent crops follow. The explanation seems to come from some recent experiments by Wagner, Maercker, Burri and Stutzer, and others. The farmyard manure, especially if fresh, so abounds in denitrifying bacteria that they destroy the nitrates rapidly and completely, free nitrogen escaping. Curiously enough, a very active denitrifying bacillus was found on straw, and we know that straw abounds in such manures.

I did not intend to go so far into agricultural details as this, but it was impossible to resist these illustrations of the splendid field of mycological research which here lies before us.

Nor can I avoid instancing at least one more example of the organisms at work in manure. We all know what enormous quantities of cellulose are manufactured daily, and even hourly, by the activity of green leaves; and when we reflect on the millions of tons of dead-wood, straw, fallen leaves, roots, &c., which would accumulate every year if not destroyed, we see at once how important is the scavenging action of the moulds and bacteria which gradually reduce these to carbon-dioxide and water, setting these gases free to enter once more into the cycle of carbon, oxygen, and hydrogen in Nature.

In 1890 Van Senus obtained two bacteria, one an aërobic and the other an anaërobic form, which in symbiotic union were found to excrete an enzyme which dissolved cellulose. Such a cellulose-dissolving enzyme I had myself isolated from the *Botrytis* of the lily-disease in 1888. In 1895 Omeliansky, working with river mud, found an anaërobic bacillus which dissolves paper with remarkable rapidity. I can only hint at the importance of these forms in connection with the

production of marsh gas in swamps, the question of the digestion of cellulose in herbivorous animals, the manufacture of ensilage, and the processes of 'shortening' of manure; and it is clear they have much to do with the destruction of paper, &c., in sewers and refuse-pits. Moreover, their further investigation promises a rich harvest of results in explanation of the rotting of stored tubers, certain diseases of plants, and several theoretical questions concerning anaërobism, butyric fermentation, and, possibly, that extremely difficult question on which Mr. Gardiner has done such excellent work, the nature of the various celluloses and constituents of the cell-wall.

I now turn to the subject of fungus epidemics, of world-wide interest, if only because the annual losses to agriculture due to epidemic diseases of plants amount to millions of pounds sterling.

The history of wheat-rust can be traced to Genesis, and at least five references to it exist in the Old Testament. The Greeks were familiar with it, and the Romans had a special deity and ceremonies devoted to it. References can be given to it in old Norman times, and Shakespeare can be quoted as acquainted with it.

According to Loverdo, a law existed in Rouen in 1660, authorising the pulling up of barberry bushes as in some mysterious way connected with rust, and in 1755 the celebrated Massachusetts law was promulgated. Eriksson refers to an English farmer destroying his neighbour's barberry in 1720.

The words *Robigo, Rubigo, Rouille, Ruggine, Rufus,* and *Rust* comprise a history in themselves, into which, however, we have not time to go, and there are many fascinating points in the history of wheat-rust which must be passed over.

Felice Fontana in 1767 probably made the first scientific investigation of rust; he distinguished the uredo- and puccinia-stages under other names, and even thought of them as rootless plants exhausting the wheat; in this, and his conviction that no remedy was possible until a careful study of all phases of the disease had been made, he was far ahead of his times.

Jethro Tull, Marshall, and Withering are the most conspicuous English names in connection with this question and period, and Marshall in 1781–84 experimented intelligently with barberry and wheat inter-planted.

Persoon in 1797 gave the name *Puccinia graminis* to the fungus. In 1805 Sir Joseph Banks described it, and suggested that the germs entered the stomata: he also warned farmers against the use of rusted litter, and made important experiments on the sowing of rusted wheat-grains.

A great discussion on the barberry question followed, in which Banks, De Candolle, Windt, Fries, and others took part, Fries particularly insisting on the difference between *Æcidium berberidis*—a name conferred by Gmelin in 1791—and *Puccinia graminis.*

De Candolle had also distinguished *Uredo rubigo-vera* in 1815, and Schmidt soon after described a third wheat-rust—*Uredo glumarum.*

Matters were at about this stage when Tulasne confirmed the statement of Henslow—one of my predecessors in Cambridge—that the uredo- and puccinia-stages really belong to the same fungus, and are not, as Unger asserted, mixed species.

Then came De Bary and his classical investigation of the whole question in 1860–64. He proved that the *sporidia* of some Uredineæ (e.g., *Coleosporium*) will not infect the plant which bears the spores, and that the æcidia of certain other forms are only stages in the life-history of species of *Uromyces* and *Puccinia.*

In 1864 De Bary attacked the question of wheat rust, and by means of numerous sowings of the teleutospores on barberry proved beyond doubt that they bring about its infection.

But De Bary did more. For the first time in history he saw the entrance of the infecting tube and the beginning of its growth in the tissues. In 1865 he demonstrated in the same faultless way the infection of the cereal by means of the æcidio-spores, and showed that *P. rubigo-vera* alternates on Boragineæ as *Æc. asperifolii*, while *P. coronata*, separated by Corda in 1837, does the same as *Æc. Rhamni* on *Rhamnus.*

Thus was discovered the astounding phenomenon of *Heterœcism,* introducing a new idea into science and clearing up mysteries right and left.

During the next twenty-five years the number of heterœcious forms has risen to about seventy, including Woronin's recent discovery of this phenomenon in an ascomycete—*Sclerotinia heterœcia.*

About 1890 the rust question entered on a new phase. In Australia, India, Sweden, Germany, and America especially, active commissions, inquiries, and experiments were set on foot, and amid some confusion of meaning among some of those concerned much knowledge has resulted from the investigations of Plowright and Soppitt in England; Barclay in India; Cobb, Anderson, and McAlpine in Australia; Arthur, Bolley, Smith Ellis, Galloway, Farlow, Harper, and others in the United States; Dietel, Klebahn, Sorauer, and others in Germany; Rostrup in Denmark; and especially from the continued and indefatigable researches of Eriksson and Henning in Sweden. This renewed work has resulted in the complete confirmation of De Bary's results, but with the further discovery that our four common cereals are attacked by no less than ten different forms of rust belonging to five separate species or 'form-species,' and with several physiological varieties, and capable of infecting the barberry. Some of these are strictly confined to one or other of the four common cereals, others can infect two or more of them, and yet others can infect various of our common wild grasses as well.

The fact that what has usually gone by the name of *Puccinia graminis* is an aggregate of several species is in itself startling enough, but this was not unexpected; the demonstration that varietal forms exist so specially adapted to their host that, although no morphological differences can be detected between them, they cannot be transferred from one cereal to another, points, however, to physiological variation of a kind met with among bacteria and yeasts, but hitherto unsuspected in these higher parasitic fungi. It now appears that we must be prepared for similar specialisation of varietal forms among *Ustilagineæ* as well as among other *Uredineæ,* as follows from the results obtained by Kellermann and Swingle in America, by Klebahn, Tubeuf, and others in Germany, and by Plowright and Soppitt in England.

Not less remarkable is the conviction that among the many different pedigree varieties of wheat, some are more susceptible to attacks of rust than others. This had often been asserted in general terms, but the extensive observations of Cobb in Australia, and the even more extensive and exact experiments of Eriksson in Sweden, seem to put the matter beyond doubt.

Of course attempts have been made to account for these differences in predisposition to the attacks of wheat-rust.

N. A. Cobb, who has done much for the investigation of Australian wheat-rusts, regards the different susceptibility to rust as due to mechanical causes, and seeks to explain it by the difference in thickness of the cell-walls on the upper and lower leaf-surfaces offering different resistance to the outbreak of the spore-clusters; the average number of stomata per square millimetre differing in the different sorts of grain, influencing the predisposition to infection; the presence of waxy bloom affording a protection, and so on.

Eriksson and Henning have made a critical examination of Cobb's mechanical theory, and show that, for Sweden at any rate, the conclusions of the Australian investigator cannot be confirmed.

Nevertheless, the problem remains. As matter of fact, different sorts of wheat, of oats, of barley, and of rye are susceptible to their particular rusts in different degrees, and the question is, Why? Some complex physiological causes must be at the bottom of it.

Sorauer pointed out in 1880 that every change of vegetative factors induces differences in composition and form of a plant, and therefore alters the predisposition of each individual and variety; and this applies to the fungus as well as to the host.

De Bary's proof, in 1886, that a Peziza succeeds in being a parasite only after saprophytic culture to a strong mycelium, that its form is altered thereby, and that probably a poison is excreted, throws side-lights on the same question; while I myself showed that similar events occur in the case of the lily disease.

Reinhardt, in 1892, showed that the apical growth of a Peziza is disturbed and interrupted if the culture solution is concentrated by evaporation or diluted; and Büsgen, in 1893, showed that *Botrytis cinerea* excretes poison at the tips of the hyphæ, confirming my results with the lily-disease in 1888, and that a similar excretion occurs in rust-fungi.

De Bary had also shown, in 1886, that the water-contents of the infected plant influence the matter; and I may remark that we have here also to consider the case of *Botrytis* attacking chrysanthemums, &c., in autumn, with respect to the chilling of the plant, which lowers the vitality of the cells and causes plasmolysis, as well as the fact that cold increases the germinating capacity of spores, as Eriksson showed.

I discussed these points at some length a few years ago in the Croonian Lecture to the Royal Society, and it now remains to see if any further gleams of light can be found in the progress of discoveries during recent years.

You are all no doubt familiar with Pfeffer's beautiful work on chemotaxis, and with the even more fascinating experiments of Engelmann, which prove that bacteria will congregate in the neighbourhood of an algal cell evolving oxygen.

When Pfeffer took the matter up in 1883, he was interested in the question as to the stimulating action of various bodies on mobile organisms, for he found that many motile antherozoids, zoospores, bacteria, &c., when free to move in a liquid, are vigorously attracted towards a point whence a given chemical substance is diffusing.

Pfeffer's problems had nothing to do with those of Engelmann; he was concerned, not with the proof of oxygen evolution or the movements of bacteria as evidence of the presence of that element, but with a fundamental question of stimulation to movement in general.

Pfeffer found that the attractive power of different chemical substances varies according to the organism, and according to the substance and its concentration. He also showed that various other bodies besides oxygen thus attract bacteria—*e.g.*, peptone, dextrose, potassium salts, &c. These experiments are by no means difficult to repeat, and are now employed in our laboratories.

During the course of several years not only were these facts confirmed, but it was also shown that this remarkable attraction—chemical attraction, or '*chemotaxis*'—is a very general phenomenon.

Pfeffer had already shown that swarmspores of the fungus *Saprolegnia* are powerfully attracted towards the muscles of a fly's leg placed in the water in which they are swimming about, and pointed out that in many cases where the hyphæ of fungi suddenly and sharply bend out of their original course to enter the body of a plant or animal, the cause of the bending lies in a powerful '*chemotropic*' action due to the attraction of some substance escaping from the body.

This idea of an attractive action between the living substance of two organisms growing in close proximity was not entirely new—it was, so to speak, in the air—*e.g.*, the fusions of mycelial cross-connections and clamp-organs, and of the spores of *Tilletia*, *Entyloma*, &c. One of the most striking examples is afforded by Kihlmann's demonstration of the parasitism of *Melanospora* on *Isaria*, where he states that some attractive action exists. In 1882 I had myself seen zoospores of *Pythium* suddenly dart on to the cut surface of a bean-stem, and there fix themselves. But it is due to Pfeffer and his pupil Miyoshi to state that they were the first to demonstrate these matters clearly.

To understand the important consequences which followed, I must now refer to another series of discoveries.

When a spore of a parasitic fungus settles on a plant, it frequently behaves as follows. The spore germinates and forms a slender tube of delicate consistence, blunt at the end and containing colourless protoplasm. De Bary long ago showed that such a tube—the germinal hypha—only grows for a short time along the surface of the organ, and its tip soon bends down and enters the plant, either through one of the stomata or by boring its way directly through the cell-walls. Several observers, and among others myself, remarked how the phenomena suggested that the end of the tube is attracted in some way and by some force which

brings its tip out of the previous direction, and De Bary even threw out the hint that this attraction might be due to some chemical substance excreted by the host-plant. I myself showed that the condition of the attacked plant affected the ease with which the tube penetrates the cell-walls, and that the actual boring of the cell-walls is due to a solvent enzyme secreted by the tip of the fungus, and in clearly demonstrating this excretion of an enzyme capable of dissolving cellulose carried a step further what was so far known, principally from De Bary's researches, as to this process. In 1892, Reinhardt showed that the tips of hyphæ curve over towards spores they are about to attack, and found that sugar-gelatine of greater strength attracts them from the same medium with a smaller proportion of sugar.

Miyoshi then showed, in 1894, that if a leaf is injected with a substance such as ammonium-chloride, dextrine, or cane-sugar, all substances capable of exerting chemotropic attraction on fungus-hyphæ, and spores of a fungus then sown on it which is *not parasitic*, the hyphæ of the fungus penetrate the stomata and behave exactly as if the fungus were a true parasite.

This astounding result throws a clear light on many known cases of fungi which are, as a rule, *not* parasitic, becoming so when the host-plant is in an abnormal condition—*e.g.*, the entry of species of *Botrytis* into living tissues when the weather is cold and damp and the light dull; the entry of *Mucor* into various fruits, such as tomatoes, apples, pears, &c., when the hyphæ meet with a slight crack or wound, through which the juices are exposed. Nay, I venture to suggest that it is even exceedingly probable that the rapid infection of potato-leaves in damp weather in July is not merely traceable to the favouring effect of the moisture on the fungus, but that the state of super-saturation of the cell-walls of the potato leaf, the tissues of which are now unduly filled with water and dissolved sugars, &c., owing to the dull light and diminished transpiration, is the primary factor which determines the easy victory of the parasite, and I suggested some time ago that the suppressed life of *Ustilagineæ*, in the stems of grasses, is due to the want of particular carbohydrates in the vegetative tissues there, but which are present in the grain.

Miyoshi, in 1895, carried to proof the demonstration that a fungus-hypha is really so attracted by substances on the other side of a membrane, and that its tip pierces the latter; for the hyphæ were made to grow through films of artificial cellulose, of collodion, of cellulose impregnated with paraffin, of parchment-paper, cork, wood, and even the chitinous coat of an insect, simply by placing the intact films on gelatine impregnated with the attracting substance, and laying the spores on the opposite side of the membrane.

Hyphæ so separated by similar membranes from gelatine to which the attracting substance was not added, did not pierce the membranes, whence we may conclude that it is really the substance referred to which incites the hyphæ to penetration.

Now, obviously, this is a point of the highest importance in the theory of parasitism and parasitic diseases, because it suggests at once that in the varying conditions of the cells, the contents of which are separated only by membranous walls from the fungus-hyphæ, whose entrance means ruin and destruction, there may be found circumstances which sometimes favour and sometimes disfavour the entrance of the hyphæ; and it is at least a remarkable fact that some of the substances which experiments prove to be highly attractive to such hyphæ—*e.g.*, sugars, the sap of plums, phosphates, nitrates, &c.—are just the substances found in plants, and the discovery that the action depends on the nature of the substance as well as on the kind of fungus, and is affected by its concentration, the temperature, and other circumstances, only confirms us in this idea.

Moreover, there are substances which repel instead of attracting the hyphæ.

Is it not, then, natural to conclude that the differences in behaviour of different parasites towards different host-plants, and towards the same host-plant under different conditions, probably depend on the chemotropic irritability of the hyphæ towards the substances formed in the cells on the other side of the membranous cell-walls? And when, as often happens, the effusion of substances such as the

cells contain to the exterior is facilitated by over-distension and super-saturation, or by actual wounds, we cannot be surprised at the consequences when a fungus, hitherto unable to enter the plant, suddenly does so.

In spite of all the progress made towards an explanation of the origin and course of an epidemic of rust, however, one serious inconsistency has always puzzled men who have worked with it in the open and on a large scale. This inconsistency concerns the outbreaks of epidemics over large areas, at periods, and within intervals, which do not agree with the weather records and the described biological facts. We know, speaking generally, the conditions of germination of the spores, we know how long infection requires, and the latent period is known: we know much as to the conditions which favour or disfavour the fungus mycelium in the tissues, and, nevertheless, an outbreak of disease over large areas sometimes occurs under conditions which appear quite inconsistent with this knowledge.

During his six years' study of the wheat rusts Eriksson was so impressed with these difficulties that he has lately committed himself to an hypothesis which may perhaps crystallise the ideas which have floated in the minds of several who have been puzzled by these matters.

The facts which seem to have finally impelled Eriksson to his hypothesis were those of the distribution of the wild rusts and grasses. Having learnt which grasses could infect the wheat, oat, barley, and rye respectively, he found cases of epidemics occurring where it was impossible to fit in the facts with the view that spores had been transferred from these grasses within the period required for infection and development of the disease spots. Again, seasons occurred when all the conditions pointed to the probability of a serious outbreak of rust, and no such epidemic occurred. Further, experiments were made in which cereals of varieties known to be susceptible to given rusts were planted in close vicinity to grasses infected with such rusts, and, nevertheless, in seasons eminently suitable for the outbreak of this particular rust on these particular cereals none appeared, or so little that it was impossible to explain the outbreaks of this same rust on this cereal elsewhere, during that season, as due to direct infection from the surrounding grasses.

More and more it became evident that the infective capacity of the rusted grasses is small, and confined to restricted areas, and that the outbreaks in certain seasons—rust-years—must be due to something other than wind-borne spores distributed by gales over the district.

Three hypotheses can be suggested to account for the non-spreading of the disease on to susceptible cereals—(1) Indisposition to germinate on the part of the spores; (2) unfavourable weather for germination; (3) some structural peculiarities of the leaves on which the spores fell, of such a nature that infection was prevented.

The results of many experiments showed that, as matter of fact, the spores are often very obstinate, and refuse to germinate even when the weather is apparently favourable, and Eriksson discovered during these experiments that cooling the ripe spores on ice increased their germinating power. Neither of the other two hypotheses mentioned could be brought into agreement with the results, however.

The conclusion was thus arrived at that an outbreak of rust cannot always be referred directly to the normal germination and infection of wind-borne spores from neighbouring centres of infection.

In some patches of extremely susceptible cereals, the disease appeared simultaneously on plants isolated from all perceptible sources of infection, and on plants not thus protected; the date of outbreak in these cases—reckoned from the sowing of the grain—was far too late to be explained by direct infection from spores on the soil, or on the grain sown. Experiments demonstrated that if such spores had been there, and germinal tubes formed as usual, the disease would have shown itself much earlier.

These and numerous other inconsistencies drove Eriksson to look for an 'internal source of infection,' in spite of the improbability of any such existing, and of its apparent incompatibility with scientific theory since De Bary's time.

Two methods were pursued. In one each plant of the cereal was enclosed from the beginning in a long glass tube, stuffed with cotton-wool above and below, and so carefully protected against infection from wind-blown spores that we may accept forthwith the improbability of such infection.

Notwithstanding these precautions, the cereal was rusted at the same time as its unprotected neighbours, and equally badly.

Granting the accuracy of the experiments, only two explanations seem to suggest themselves. Either (1) winter-spores attached to the grain had germinated and infected the young seedling—a not impossible event, since several observers have found spore-bearing mycelia in the pericarp of the ripe grains, and we know these spores can conserve their germinating power for months; or (2) the infective material had been handed down to the embryo from the parent plant—an almost inconceivable hypothesis.

To answer this question Eriksson protected his seed-plants from external infection, and sowed the grains in sterilised soil in specially constructed green-houses, through which the air can only pass *viâ* cotton-wool filters. Between the double-glass windows water was allowed to stream, and the plants thus kept cool. Some of these protected plants became rusted.

Before we draw any conclusions from such difficult experiments as the above, let us see the results of microscopic examination.

Reference has already been made to the mycelium and spores in the tissues of the pericarp of the grain; no trace could be, or ever has been, detected in the endosperm or embryo. In some cases the seedlings, four to eight weeks old, showed the first uredo-pustules on their leaves, and the mycelium but no spores could be detected in the seed-coats.

The tissues of the leaf, in the neighbourhood of young uredo-pustules, frequently showed curious clumps of protoplasm in the cells, either free in the cell-cavity, or attached to the primordial utricle, and looking like haustoria. Eriksson assumes that we have here the key to the puzzle; he regards these 'plasmatic corpuscles' as the protoplasm of the fungus which, after leading a dormant life commingled symbiotically with the living protoplasm of the cell, is now gaining the upper hand and beginning to form a dominant mycelium.

We are therefore to suppose that when the spores of rust, even if of the right variety, alight on the tissues of a wheat-plant, it is a matter decided by external and internal conditions whether the germ-tubes forthwith infect the plant and grow out into a dominant, parasitic, sporiferous mycelium, as we know they usually do, or simply manage to infect the cells with enough protoplasm to live a latent symbiotic life for weeks—or even months—as a *Mycoplasma*, which may, under favourable circumstances, gain the upper hand, and grow out in the form of a mycelium.

This is a startling hypothesis, and brings us to the most advanced point along this line of biological speculation. We must distinguish sharply and clearly between such a view, which is by no means inconsistent with all we know of parasites, so far as the dormant mycelium goes, and all the hazy, mystical suggestions as to 'infective substance' and so forth, which were so freely flung about at the beginning of this epoch, and which De Bary's strictly scientific methods put down so firmly.

The idea of symbiosis is now comparatively old, and there are many cases of dormant life now well established. Even the astounding notion of blended protoplasms can no longer be regarded as new. I need only remind you of Cornu's *Rozella*, which invades the thallus of *Saprolegnia*, and *Woronina* in *Vaucheria*, the protoplasm of the two organisms apparently blending and living a common life for some time before the true nature of the parasite manifests itself. Eriksson has avowedly been influenced by these and other cases among the *Chrytridiaceæ*. That the remarkable intra-cellular fusions of *Plasmodiophora* and the now well-established symbiosis of the organism of the leguminous root-nodules have also had their influence on his work may well be assumed, and I think we may trace also the effects of our knowledge of the latent life of *Ustilago* during the vegetative period of the attacked cereal.

But there are other cases which prevent our casting aside as impossible the view that Eriksson has put forward.

I showed some years ago that the mycelium of the *Botrytis* of the lily disease can lie dormant for some time in the cell-walls, and I have observations showing that other forms of *Botrytis* which attack roses and chrysanthemums only gain the upper hand when the cold autumn nights so chill the attacked cells that they succumb; the mycelium was there long before, but so long as the cells were active no progress could be made, and only when the plasmolysed chilled cells exude their sap can the mycelium advance.

Many cases of similarly dormant mycelia appear to exist in those cortex and cambium diseases which result in the production of cankers—e.g., *Nectria ditissima* and *Peziza Willkommii*, and Tubeuf's experiments with *Gymnosporangium* are even more suggestive. Tubeuf found that if *G. clavariæforme* is sown on hawthorn seedlings the fungus forms yellow spots and induces marked hypertrophy, and normal spermogonia and æcidia—*Roestelia lacerata*—are developed; but if *Pyrus Aucuparia* is used as the host, no yellow spots or hypertrophy result, though a mycelium is formed and will even produce a few starved spermogonia. On allied species of *Pyrus* the fungus may even succeed in forming a few poorly developed æcidia. But on the quince the fungus only just succeeds in establishing an infecting mycelium, and soon dies; and Wagner describes similar events with fungi on *Stellaria*.

These cases point to a struggle between the protoplasm of the cells of the different hosts, and of the fungus respectively: sometimes one wins, sometimes the other. The following cases are also suggestive. De Bary found that the germinal hyphæ of *Peronospora pygmæa*, which is parasitic on *Anemone*, will penetrate the tissues of *Ranunculus Ficaria*, but cannot maintain its hold, and the mycelium soon succumbs and dies.

Still more remarkable and to the point is the following case. Soppitt and Plowright in England, and Klebahn and others on the Continent, have gradually unravelled a curious case of heterœcism and specialised parasitism among certain *Puccinias* found on *Smilax*, *Convallaria*, *Paris*, and *Digraphis*. The story is too long to recount in detail, but the *Puccinia-spores* from *Phalaris* were found by Klebahn to refuse to infect *Polygonatum* leaves successfully, though they readily infect the allied *Convallaria*. Close investigation showed, however, that although the sporidia failed to develop a mycelium in the *Polygonatum* leaves, they really penetrate the cells, and the delicate germ-tube is killed off by the protoplasm, a red spot marking the place of entrance.

The perennial mycelia of Witches' Brooms, æcidia in Euphorbia, *Taphrina*, and many other perennial mycelia are also cases in point.

It is not my purpose to hold a brief for Eriksson's hypothesis, but I may point out that it is in no way contradictory to the facts already known since De Bary's time. Its most serious aspect is with regard to possible treatment, and it is obviously essential that we should have it tested to the utmost, for it must be remembered that no method of spraying or dusting has been, or apparently can be, devised for cereals; hence the questions as to the existence of really resistent forms, and whether dormant mycelia lurking in their tissues have deceived us in these cases also, require sifting to the bottom. Experience, so far, points to the selection of pedigree wheats and careful cultivation as the first necessities; how far the question of spring *versus* winter wheat aids us is still matter for further experiment; early and late ripening are also concerned. Climate we cannot hope to control, but it remains to be seen—when the facts are known—how far it can be 'dodged.'

Clearly what is needed, then, is experiments with varieties of wheat under all conditions, and we may congratulate the Australian, Swedish, and United States experimental stations on their preliminary efforts in this direction.

I have only been able to give a mere sketch of this rapidly growing subject, but I think you will agree that we are justified in saying that an epidemic of parasitic fungi depends on the interaction of many factors, congenital variations of the host-plant and topical variations of its cell-contents being probably among the most important; and since we cannot hope to control the variations of the parasite, or the meteorological conditions, it behoves agriculturists to pay more systematic

attention to the selection of those varieties of the cereal which are least predisposed to rust.

When we find the annual losses from wheat-rust alone put down at sums varying from 1,000,000*l.* to 20,000,000*l.* in each of the great wheat-growing countries of Europe, India, Australia, the United States, and elsewhere, it strikes one as very remarkable that so little should be done to encourage the scientific investigation of these practical questions. I need hardly say that the establishment and maintenance of a fully equipped laboratory and experimental station does not cost the interest on the smallest of these sums.

It should be also clear that in the further development of our knowledge of the treatment of parasitic diseases of plants the farmer, gardener, and forester can alone supply the experimental evidence which will enable us to put theory to the test in the field, garden, and forest. The botanist, by means of his pure cultures of the fungus, can now show clearly what stage in the life-history of a parasite is vulnerable. In his 'microscopic gardens' he can show what antiseptics may be employed, how strong they should be, and when and how they should be employed.

But we must not forget that it is one thing to kill a fungus when grown pure, and another to kill it when growing on or in, or even associated with, other plants, without harming the latter. We may compare the first case to the destruction of weeds on a gravel path, where the antiseptic dressing may be employed lavishly and at any time, because there are no other plants to injure; but it is another matter to kill the same weeds growing in a lawn or a flower-bed, where we have to pay attention to the neighbouring plants.

Experiments in the open, simple in themselves, but conducted intelligently and with due regard to the rigorous demands of science, can alone determine these questions.

Brewers have long known that burning sulphur in the barrels will rid these barrels of the moulds and yeasts growing on their damp beer-soaked sides; and Berkeley saw clearly that sulphur could be applied to the outside of plants on which such fungi as the hop- or grape-mildew, &c., are growing, the critical period being when the spores are germinating, so that the slowly oxidising sulphur should evolve sulphurous acid in just sufficient quantities to destroy the delicate germs without injuring the leaves. And even better results have been attained with Bordeaux mixture.

But it is clear that this can only be done with an intelligent appreciation of the life-history of the fungus, and a knowledge of when the germinating stage is at hand. The successes obtained in France and America with Bordeaux mixture attest this.

It would obviously be absurd to powder sulphur or spray liquids over plants attacked by bunt- or smut-fungi, for we know that the germ-tubes only infect the germinating grain as its first root emerges. Here, as was shown long ago, and especially by the experiments of Hoffmann, Kühn, and De Bary, the practice known as 'dressing the grain' must be followed. Knowing that the spores of the fungus are attached to the grain, or to particles of soil around, the efforts must be directed to covering the outside of the grain with an antiseptic which is strong enough to kill the germs but not the grain. If the land is known to be clean, the grain may be immersed in hot water, the temperature being experimentally determined, and high enough to kill the spores but not the wheat, and so on. In these matters also the American stations have done good work.

Neither of these classes of treatment can be adopted, on the other hand, for diseases such as 'Finger and Toes,' where we have a delicate slime-fungus making its way into the roots already in the soil; but, here again, intelligently devised experiments, such as those of Somerville and Massee, have shown that liming the soil renders it so unfavourable to this disease that it can be coped with.

And similarly with other diseases; the particular methods of dealing with the 'damping-off' of seedlings, 'dry-rot' in timber, the various diseases of trees, and so on, do and must differ in each case, and the guiding principle must be always the same—having learnt all that can be learnt of the habits of the fungus and of

the host, and of the relationships of each to the other and the environment, to see how it is possible to step in at the critical moment and interfere with these relationships in the direction desired by human interests.

The whole matter thus resolves itself into a study of variation—a purely experimental inquiry into complex biological relationships, and it is encouraging to see that this is being understood in the large American and other stations, which are distinguishing themselves by their efforts.

THURSDAY, AUGUST 19.

The following Reports and Papers were read :—

1. *Report on the Preservation of Plants for Exhibition.*
See Reports, p. 537.

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2. *Report on the Fertilisation of the Phæophyceæ.*
See Reports, p. 537.

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3. *The Growth of the Mycelium of* Aecidium graveolens (Shuttlew.) *on the Branches of the Witches' Broom on* Berberis vulgaris. *By* P. MAGNUS, *Berlin.*

Eriksson has stated in the 'Beiträge zur Biologie der Pflanzen (Bd. VIII., Heft I.) that the mycelium of the Aecidium producing the witches' broom of the barbery grew within the cells of the cambium. In the 'Berichte der deutsch. bot. Gesellschaft,' Bd. XV., I asserted that the mycelium was intercellular with haustoria in the pith, cortex, and in the phloem. In the same volume of the 'Berichte,' Eriksson states (pp. 228-231) that he had only examined the cambium, and I only the pith and the cortex, and the latter statement was correct. He also pointed out that he had examined fresh material, whereas mine had been preserved in alcohol, which objection I did not consider of any value. I have examined, therefore, this summer some fresh material which was kindly sent me by Messrs. Bäumler and Reuter, and have renewed my investigations on the growth of the mycelium in the new shoots of the witches' broom. I find my former statements confirmed. The mycelium grows in the intercellular spaces of the pith, cortex, soft bast, and of the medullary rays, and as I have mentioned (*loc. cit.*) it often causes the walls of the cells between which it grows to swell up. It sends numerous generally knot-like haustoria into the cells. At the end of April or at the beginning of May many of the short rosette-like shoots of the barbery, the leaves of which were covered in spring with aecidia and spermogonia, grow out into long shoots. Into the pith of these shoots the mycelium enters, and it keeps pace with the growth of the medullary cells, so that its ends reach into the meristem of the terminal bud. From the pith the hyphæ pass through the medullary rays into the primary cortex, and especially through the original tissue rays opposite the insertion of the leaves. Hence it reaches the axillary buds, and makes its way into their first leaves, which will expand in the next spring. The hyphæ which are figured by Eriksson within the cambium cells, I consider to be the cell contents contracted by plasmolysis; the yellow granules which Eriksson observed in them might, in my opinion, be the first appearance of the yellow colouring matter which fills the young wood-cells of Berberis.

Lastly, I have to point out that I had identified this aecidium of the barbery in 1875 with *Aecidium magellanicum*, Berk., and all other observers have followed me in this respect. Since then I have shown that another aecidium is found in Patagonia and Chili, producing witches' brooms on *Berberis buxifolia,* and this I

have named *Aecidium Jacobsthalii*, Henrici, and I consider that the *Aecidium magellanicum* observed by Berkeley on *Berberis ilicifolia* should be distinguished from the two above-mentioned aecidia.

The fungus causing the witches' broom on the barbery in Europe should therefore no longer be called *Aecidium magellanicum*, Berk., but must be called either *Aecidium graveolens*, Shuttlew., or aecidium form of *Puccinia Arrhenatheri* (Kleb.), Erikss.

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4. Stereum hirsutum, *a Wood-destroying Fungus. By* H. MARSHALL WARD, *D.Sc., F.R.S., Professor of Botany in the University of Cambridge.*

The author has cultivated this fungus from the spores, on sterilised wood blocks, and has not only obtained very vigorous pure cultures, and traced the action of the mycelium week by week on the elements of the wood, but has obtained spore-bearing hymenia, and worked out the life-history very completely. Hartig, in his 'Zersetzungserscheinungen des Holzes,' examined the wood-destroying action of this fungus, but used material growing in the open, and therefore not pure. Brefeld attempted its culture, but failed to make it develop any fructification or spores; since Brefeld does not allow us to know the composition of his media, it is not possible to suggest why he failed.

The fertile hymenium arises in about three to four months, and the author has examined the development very thoroughly, and refers to discrepancies in the existing descriptions. The details of its destruction of the wood are also gone into fully; the fungus delignifies the inner layers of the walls of the wood-elements, and in three months' cultures and upwards these turn blue in chlor-zinc-iodine, and are shown by other reagents to undergo alteration to cellulose-like bodies before their final consumption by the fungus.

Drawings and lantern slides made by Mr. Ellis from the author's preparations were shown.

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5. *The Nucleus of the Yeast Plant. By* HAROLD WAGER.

Of the numerous observers, some twenty in number, who have made observations upon the presence of a nucleus in the yeast plant three only actually deny its existence. Many conflicting statements, however, have been made as to its nature, some observers having described it as a perfectly homogeneous body, others as possessing a nuclear membrane and nucleolus, whilst two observers regard certain granules present in the cell under certain conditions as of the nature of a nucleus.

In *Saccharomyces cereviseæ* the nucleus can be easily demonstrated by careful staining in hæmatoxylin, Hartog's double stain of nigrosin and carmine, or by staining in aniline-water solution of gentian violet. It appears to consist, in the majority of cases, of a homogeneous substance, spherical in shape, placed between the cell wall and the vacuole. By very careful staining, however, and especially after digestion in pepsin glycerine solution, a granular structure can be observed. The whole cell is in the normal, undigested state, often pervaded by such a deeply stainable substance that this granular structure is difficult to make out. On the whole, perhaps, it resembles more than anything else the fragmenting nuclei in the older leaf cells of Chara; that is, it consists of deeply stained granules embedded in a slightly less stainable matrix. These granules are probably chromatin granules, and the matrix occasionally gives evidence of a slight granular structure.

The process of budding in a yeast cell is accompanied by the division of this nucleus into two. The division is a direct one, and does not take place in the mother cell, but in the neck joining it to the daughter cell. When about to divide, the nucleus places itself just at the opening of this neck, and proceeds to make its way through it into the daughter cell, until about half of it has passed through, when it divides completely, and the two nuclei thus formed separate from each other towards the opposite sides of their respective cells.

In *S. Ludwigii* the nucleus appears to possess the normal structure of a nucleus a nuclear membrane being present, together with a nuclear network and a nucleolus. The nucleolus appears to contain all the chromatin substance, and in the process of division increases in size and divides into two, each portion becoming a new nucleus.

In *S. Pastorianus* the nucleus is similar in structure to that of *S. Ludwigii*, except that a distinct nuclear network could not be seen. The process of division is likewise similar to that observed in *S. Ludwigii.*

The process of spore-formation was observed in *S. cerevisecæ*. In a cell about to sporulate the large vacuole or vacuoles disappear, and the protoplasm becomes filled with a large number of very small ones, so that its texture appears spongy. At this stage the nucleus is found in the centre of the cell, and appears to be homogeneous in structure. Soon, however, deeply stained granules appear in it, and these accumulate in the centre, forming a spherical mass, which looks exactly like a nucleolus. When this nucleus divides its outline becomes irregular, and the granules arrange themselves in the form of a short rod surrounded by the other portion of the nucleus, which stains differently and appears to form a structure of the nature of a spindle. The granules separate into two groups, and each group becomes a nucleus. The two nuclei thus formed again divide, and four nuclei are produced, each of which becomes the nucleus of a spore. A small quantity of protoplasm accumulates round each nucleus, spore membranes appear, and four spores are thus formed, standing in the remainder of the protoplasm, from which ultimately the thick spore membranes are produced.

We may, I think, regard the process of nuclear division in spore-formation as a simple form of karyokinesis.

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6. *A Disease of Tomatoes.* *By* W. G. P. Ellis, *M.A., Cambridge.*

From diseased tomatoes received in August 1896 from Jersey the associated fungi and bacteria were isolated and cultivated on nutrient gelatine, and the mycelium was traced in sections of the fruits. On removing the first skin with carefully sterilised instruments the mycelium within the fruit formed in a short time the well-known sporangiophores of *Mucor stolonifer.* Though late in the season (August 31, 1896), infection of sound plants at the University Botanic Gardens, Cambridge, from pure cultures caused a disease resembling that of the fruits received in August and September from the grower. Experiments are now (July 1897) in progress to determine (1) whether the fungi obtained, other than *Mucor stolonifer*, cause disease, and (2) the site of infection.

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7. *On the Chimney-shaped Stomata of* Holacantha Emoryi. *By* Professor Charles E. Bessey.

This prickly, leafless shrub, called the 'Burro Thorn,' 'Sacred Thorn,' 'Crucifixion Thorn,' 'Corono de Christo,' &c., is a native of the arid regions of Southern Arizona, where it was discovered fifty years ago by Major Emory, of the United States Army. It is supplied with remarkable breathing pores, which are evidently designed to enable the plant to obtain carbon dioxide, while at the same time preventing the loss of water from its interior moist tissues. The epidermis is of extraordinary thickness, and the stomata have long, narrow, chimney-shaped openings above them, terminating in hollow papillæ, which project some distance above the surface.

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8. *Some Considerations upon the Functions of Stomata.* *By* Professor Charles E. Bessey.

The author summarily reviewed the structure of stomata and discussed the needs of aquatic, terrestrial, and aerial plants as to their getting of food, and the

means by which they resist the drying of their tissues. The facts cited are held by him to indicate that respiration is the normal function of stomata, and that the loss of water through stomata is incidental and secondary. The author concludes :—

1. That one of the functions of stomata is the admission of carbon dioxide to the chlorophyll-bearing tissues of the plant for use in the formation of the carbohydrates. 2. That the loss of water by terrestrial plants was originally hurtful, and is so now in many cases. 3. That if plants have utilised this constant phenomenon, it is for the supply of food matters of secondary importance, as the salts in solution in the water of the soil. He cites observations and experiments to corroborate his views. Thus Stahl and Blackman have shown that carbon di-oxide enters through the stomata ; Stahl has shown, also, that transpiration takes place through the stomata, but many observations show that stomata quickly close when the water supply is deficient. Stahl, again, has shown that the leaves of evergreens have their stomata closed during the times when no carbon assimilation can take place (that is, in winter) ; observations show that green parasites (mistletoe, &c.) have many stomata, while those not green (dodders, &c.) have scarcely any.

FRIDAY, AUGUST 20.

The President's Address was delivered. See p. 831.

The following Papers were read :—

1. *On the Species of Picea occurring in North-eastern United States and Canada. By* Professor D. P. Penhallow.

Since the time of Pursh the validity of the red spruce as a distinct species has been generally denied by systematic botanists. In 1887 the late Dr. George Lawson maintained, in a paper before the Royal Society of Canada, that the red and black spruces are distinct species. This view has been sustained during the past year by Britton in his 'Illustrated Flora of North America.' My own studies prosecuted during the past two years have likewise shown that there are abundant reasons for the separation of *P. rubra* as a distinct species.

Incidentally attention has been directed to a form of the white spruce characterised by its fœtid odour and its strongly glaucous, rigid, and often cuspidate leaves, which are commonly produced at the base. For this the name *fœtida* is suggested.

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2. *Contribution to the Life History of Ranunculus. By* Professor Coulter.

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3. *On the Distribution of the Native Trees of Nebraska. By* Professor Charles E. Bessey.

The State of Nebraska occupies a central position in that portion of the North American continent where forest trees may grow. In this great area it lies almost centrally again within the prairie region, which extends from the Mississippi River to the Rocky Mountains, and stretches from Saskatchewan to Texas. Beginning with an elevation of a little less than 300 metres along the Missouri River, which forms its eastern boundary, it rises gradually to an altitude of about 1,700 metres near its western border. From east to west it is an undulating plain whose western edge has been much uplifted. Down this slope run the Niobrara, the Platte, and the Republican Rivers, each a turbid mountain torrent rushing swiftly and directly from the Rocky Mountains or the foot-hills to the Missouri River.

Across the central part of the State a broad belt of sand-hills stretches from north-east to south-west. From these arise many small rivers of clear water, filtered through the sands, and issuing in never-failing springs. Thus arise the Middle Loup, North Loup, Calamus, South Loup, Shell, and the Elkhorn Rivers and their numerous branches. Lastly, in the basin of the south-eastern quarter there flow in different directions several alluvial streams, whose muddy waters run sluggishly into the Republican, the Missouri, and the Platte Rivers.

South-eastward of this area lie the heavy forests which characterise many portions of Missouri. Southward lies the southern extension of the Great Plains, while northward the plains continue to the international boundary and far beyond. Eastward lie the undulating prairies of Iowa, with their streams bordered by narrow belts of forest trees. Westward are the forests of the Rocky Mountains, extending eastward upon the Black Hills of South Dakota, and the foot-hills of Wyoming and Western Nebraska, namely Pine Ridge, north of the Niobrara River and Cheyenne Ridge, between the North Platte and Lodge Pole Rivers.

In this area, in the centre of the plains, the native trees of the South-eastern Missouri forests, and the Western Rocky Mountain forests have pushed until there are now about sixty-five species of trees which grow naturally within its limits. Of this number fully fifty-six came from the Missouri forests, and but nine from the Rocky Mountains.

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4. *The Vegetation Regions of the Prairie Province.* *By* Roscoe Pound *and* Frederic E. Clements.

A portion of the paper is devoted to a critique of the treatment accorded by various authors to the floral covering of the North American continent, and in particular to that given by Drude in his 'Handbuch der Pflanzengeographie.' Especial attention is paid to the latter's characterisation of the Great Plains, and the details are discussed at considerable length. The authors endeavour to demonstrate the integrity of the Great Plains as a single vegetation province, and, in so doing, summarise the most salient features of the floristic. Finally, the vegetation regions of the prairie province are outlined briefly, followed by a concise summary of the characteristic formations.

There are three general classes of formations, comprising a considerable number of types, viz., the prairie formations, prairie-grass, buffalo-grass formations, the sand-hill formations, bunch-grass, blowout, and sand-draw formations, the foot-hill formations, the undershrub formation of tableland and bad land, the mat and rosette formation of buttes and hills, and the grass formation of high prairie and sandy plains.

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5. *The Zonal Constitution and Disposition of Plant Formations.* *By* Frederic E. Clements.

The author has here reviewed the phytogeographical contributions bearing upon the subject in hand, with especial reference to the part they have played in the elaboration of the conception of zonation. In addition, he has endeavoured to demonstrate the fundamental universality of zonation in all divisions of the floral covering. The essential connection between lines of stress which are physical, tensions which are biological, and zones which are phytogeographical is brought out, and the causation of these phenomena briefly discussed. Lines of stress are symmetrical or asymmetrical. Continental lines of stress are asymmetrical. They are transverse, in which case they are primary, and give rise to vegetation zones, or longitudinal, when they are secondary, and originate vegetation provinces. There are also tertiary lines of stress, which are likewise asymmetrical, and define vegetation regions. Symmetrical lines of stress produce bilaterally or radially symmetrical tensions. Each may be the result of biological or topographical symmetry, so that various portions of the floral covering may manifest zonation,

due to either bilateral or radial biological symmetry, or to bilateral or radial topographical symmetry. Zonal and azonal formations are contrasted, and the latter shown to be rare and atypical.

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6. *The Transition Region of the Caryophyllales.* *By* Frederic E. Clements.

The history of the investigation of the transition region is discussed at considerable length. After a concise sketch of the histogenetic changes in the transition region in general, the details of the process are given for selected genera, Dianthus, Portulaca, Allionia, Phytolacca, Polygonum, and Rumex. Three types of transition may be distinguished with respect to the constitution of the bundle trace of the cotyledons: holostelar, where the trace is composed of the entire vascular system of the hypocotyledonary stele; prototracheidal, when the prototracheids are the xylem elements to pass into the cotyledons; metatracheidal, when the cotyledonary trace is formed by the metatracheids. With reference to the perfection of the transition in the hypocotyl, the transition may be truncate or complete. In the first case, the xylem and phloëm reach the cotyledons in centripetal or secantial orientation; in the second, the orientation is centrifugal, and the stele becomes collateral.

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7. *Note on Pleurococcus.* *By* Dorothea F. M. Pertz, *Cambridge.*

Cultures of Pleurococcus in nutritive solutions were made during the winter months, from November to April. They did well in Knop's solution, ·2 per cent., in sterilised glass dishes and flasks, which were placed in different situations; in the laboratory, in a greenhouse, and out of doors.

Separate clusters of Pleurococcus in hanging drops of the same solution were also observed as continuously as possible. These drops were suspended in carefully sterilised moist chambers, which were kept for several weeks, in one case for two months.

The chief difficulties met with were, first, to obtain the Pleurococcus in absolutely pure condition, and then to keep it sufficiently aërated without running any risk of making the culture impure. Both the 'globular sporangia' and those of 'elongated or quadrangular form,' observed by Chodat, occurred frequently, and they seem undoubtedly to be produced by the transformation of normal Pleurococcus-cells. Individual sporangia were repeatedly selected for special observation, and the process by which they break up into separate spores was noted at all its stages.

The filamentous form described by Chodat never occurred.

MONDAY, AUGUST 23.

The following Papers were read:—

1. *Antherozoids of* Zamia integrifolia.[1] *By* Herbert J. Webber, *M.A., Washington, D.C.*

The occurrence of motile antherozoids in Zamia confirms their recent discovery in Gingko and Cycas by the Japanese investigators Hïrase and Ikeno. The develop-

[1] For fuller details see 'Peculiar Structures Occurring in the Pollen Tube of Zamia,' *Bot. Gazette*, vol. xxiii., June 1897, p. 453; 'The Development of the Antherozoids of Zamia,' *Bot. Gazette*, vol. xxiv., July 1897, p. 16; 'Notes on the Fecundation of Zamia and the Pollen Tube Apparatus of Gingko,' *Bot. Gazette*, vol. xxiv., October 1897, p. 255.

ment of the antherozoids in Zamia is unique. In the generative cell two comparatively very large bodies are found accompanying the nucleus, which very greatly resemble centrosomes, but which differ from any centrosomes that have been described. The generative cell divides, forming two daughter-cells, each of which forms a motile antherozoid. In the prophases of the division the centrosome-like bodies increase in size, becoming from 18 to 20 μ in diameter, an exterior wall becomes plainly distinguishable, and the contents become vacuolate. During the formation of the spindle, the kinoplasmic filaments centered upon the centrosom-like bodies entirely disappear, apparently being utilised in forming the spindle. The spindle is internuclear, the filaments having no visible connection with the centrosome. In the monaster stage of the division the outer membrane of the centrosome-like bodies has the appearance of breaking up into fragments, the contents contracting away from the wall. During the formation of the cell-plate the outer membrane may be seen to have broken, and the contents are then visible as a small cluster of granules in the cytoplasm. The membrane formed by the broken wall of the centrosome-like bodies becomes extended in length, forming a band which moves outward and becomes appressed against the Hautschicht of the antherozoid cell. This band grows in length, finally forming from 5 to 6 turns around the cell, which are arranged in the form of a helicoid spiral. While this band is still short, protuberances can be noticed on its outer surface, which ultimately grow into the motile cilia of the mature antherozoid. The antherozoids of Zamia are surprisingly large, being plainly visible to the unaided eye. They are ovate or compressed, spherical in shape, and from 258 to 332 μ in length by 258 to 306 μ in width. Their motion and development were studied in 10 per cent. sugar solution, in which they could be kept living and moving for over two hours. In fecundation from two to four antherozoids enter each archegonium, only one of which takes part in fecundation. In the actual process of fecundation, the nucleus only appears to take part, the cytoplasm and cilia bearing band probably remaining in the cytoplasm of the archegonium. The first division of the fecundated oosphere has not been observed. In later divisions, however, which have been carefully studied no indication of centrosomes could be found. The centrosome-like body in Zamia seems thus to be a temporary organ of the cell, having the special and unique function of forming the motile organs of the antherozoid.

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2. *On Diagrams illustrating the result of Fifty Years' Experimenting on the Growth of Wheat at Rothamsted, England. By* Dr. H. E. Armstrong, *F.R.S.*

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3. *A Preliminary Account of a New Method of Investigating the Behaviour of Stomata. By* Francis Darwin, *F.R.S.*

The method resembles in principle Stahl's cobalt test, inasmuch as it only indirectly indicates the condition of the stomata. Both are, strictly speaking, methods for localising the transpiration of leaves, and both, to some degree, measure the amount of transpiration. The instrument made use of in the present researches is a hygroscope depending for its action on the extreme sensitiveness to watery vapour of certain substances. The best material consists of thin sheets of horn treated in a special manner, and known as 'Chinese sensitive leaf.' The other is what is used for the toys described as 'fortune-telling ladies,' 'magical fish,' &c. When either of these membranes is placed on a damp surface it instantly curves with the concavity away from the source of moisture. If one end of a strip of the material is fixed to the lower surface of a block of cork, and is placed on the stomatal face of a leaf, it is clear that only the free end can rise. It is on this principle that the hygroscope is constructed, the angle to which the hygroscope tongue rises being a rough indication of the degree of transpiration. Thus on a leaf having stomata only below, the index of the hygroscope remains at zero on the upper surface of the leaf, while on the lower side it instantly rises to

an angle varying with the condition of the stomata. If they are widely open the angle will be 30° or 40° to a horizontal line; if the stomata are closed the reading will be zero on both surfaces of the leaf. With this instrument a number of well-known facts in the physiology of the stomata can be easily demonstrated. The author is engaged in a general investigation of the behaviour of the stomata under varying conditions.

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4. *Notes on Lilæa.* *By* Professor CAMPBELL.

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5. *Lecture on Fossil Plants.* *By* A. C. SEWARD, *M.A.*

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6. *On the Existence of Motile Antherozoids in the Dictyolaceæ.* *By* J. L. WILLIAMS.

TUESDAY, AUGUST 24.

A joint discussion with Section I on the Chemistry and Structure of the Cell was introduced by the reading of the following Papers:—

(1) *The Rationale of Chemical Synthesis.* *By* Professor R. MELDOLA, *F.R.S.*

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(2) *On the Existence of an Alcohol-producing Enzyme in Yeast.* *By* Professor J. R. GREEN, *F.R.S.*

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(3) *The Origin and Significance of Intracellular Structures.* *By* Professor A. B. MACALLUM, *Ph.D.*

The following Papers were then read:—

1. *Further Observations on the Insemination of Ferns, and specially on the Production of an Athyrioid* Asplenium Trichomanes. *By* E. J. LOWE, *F.R.S.*

At the meeting of the British Association at Cardiff in 1891 the author used the term multiple parentage. Since then a biological committee of the Royal Society has been formed, and the term insemination has been used in the case of animals. As a member of that committee the author uses the term insemination of plants in preference to that of multiple parentage.

The author records experiments in these insemination of *Asplenium Trichomanes* with *Asplenium marinum* and *Athyrium filix fœmina.*

In the hybrid Trichomanes the length of the frond is six inches, of which the lower half is *bipinnate* and two inches wide, the upper half being pinnate, with long narrow pinnæ. Some of the fronds are pinnate from the base to the apex, and these have very long pinnæ, especially near the base, some being as much as three-quarters of an inch in length.

Although copiously fertile and giving promise of a crop of seedlings, it has yet to be proved whether it may not be similar to the hybrid between *Aspidium aculeatum* and *Aspidium angulare*, whose spores looked equally promising, though practically sterile, for the sowings of many thousand spores (persevered in for a

number of years) have only resulted in three or four plants; but these three or four are, however, not only copiously fertile, but have produced many plants.

In the athyrioid Trichomanes the only peculiarity connecting it with *Asplenium marinum* consists in the long narrow pinnæ being substituted for the usual rounded ones, and in the basal pinnæ being large, which is not the case in other forms of *Asplenium Trichomanes.* The change from pinnate to bipinnate is evidence of a cross with Athyrium, for the author has never heard of a bipinnate-fronded *Asplenium Trichomanes*; the bipinnate lower half of the fronds have the pinnæ bent, some even at right angles to the frond (as is the case with the variety of *Asplenium Trichomanes* that was used in this cross). These pinnæ being bent at right angles makes it impossible to show the character with a pressed frond. The reproductive organs largely imitate *Asplenium Trichomanes.* A portion of the fronds are not bipinnate, and in these the pinnæ are very large at the base.

Two plants having this bipinnate character are almost identical, and some others now approaching maturity will be very similar, whilst others show no attempt up to the present time to be bipinnate, and these have the large lengthy pinnæ of the sea spleenwort.

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2. *On more than one Plant from the same Prothallus. By* E. J. Lowe, *F.R.S.*

Experiments have now contradicted the assertion that only one cell on a prothallus can be impregnated, and that only one plant can be produced.

It must be borne in mind that what holds good in a wild state does not necessarily affect artificial impregnation, *i.e.*, where the strongest survive, to the destruction of the weaker. Taking two notable examples, the variety *victoriæ* of the lady fern and the *cristatum* of the *Nephrodium palleaceum*, both remarkable varieties, and now to be seen in every good fernery, have never again been found growing wild, although by artificial culture they are raised by thousands.

In artificially cultivated plants we have some important instances. In 1885 an Athyrium was inseminated with eight varieties, and amongst the plants three were found growing so closely together as to be difficult to separate. These eventually proved to be all alike, and were moreover so remarkable from having *two kinds of fronds* (the first instance known in the lady fern) as to make it certain they were produced on the same prothallus. Again, in 1889 there was the case of a Scolopendrium, in which four varieties of a Scolopendrium from insemination produced three plants under similar circumstances. These were also alike, and had fronds that were undulate, muricate, periferent, and caudate, the tail or horn being $2\frac{1}{2}$ inches long and branched.

Further experiments, in which immediately on a frond appearing it was removed, caused the prothallus to throw out other branches or fronds, which were as speedily removed; and in this way seven plants resulted from this one prothallus, but this development was most conclusively shown in the experiment of dividing and repeatedly subdividing a prothallus, as then forty plants were obtained, and the prothallus divisions kept healthy for several years, although for several years previously they had been kept alive and unimpregnated.

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3. *Results in Experiments in the Cross-fertilising of Plants, Shrubs, and Trees. By* Wm. Saunders, *Director of the Dominion Experimental Farms.*

In this Paper the writer gives an account of the results achieved by experiments conducted by him during the past twenty-five years in the cross-fertilising of plants, trees, and shrubs. This work has included experiments with different sorts of wheat, barley, oats, pease, and rye; also with different varieties of the gooseberry, red currant, white currant, black currant, raspberry, blackberry, grape,

apple, pear, plum, and cherry, and with several species of ornamental shrubs and wild flowers.

Among the most interesting results obtained with fruits may be mentioned some hybrids between the black currant as female and the gooseberry as male, which show in a very striking manner the influence of both parents. In the hybrids the leaves are intermediate in form and character. In all but two instances the leaves have no odour when bruised, and in these the characteristic odour of the black currant is but faintly perceptible. The flowers also are intermediate in the size of the clusters and the number of flowers on each. Even in the structure of the pistil the flower partakes of the characteristics of both parents. In the black currant it is single, short, and robust; in the gooseberry it is long and slender, and divided to the base; in the hybrid the pistil is cleft halfway down. Very little fruit has yet been produced, but the berries thus far have been borne singly, and are of a dull reddish colour.

The gooseberry sawfly, *Nematus Ribesii*, which does not eat the foliage of the black currant, feeds on the leaves of the hybrids; the gooseberry mildew also, *Sphærotheca Mors-uvæ*, which does not affect the black currant, attacks these hybrids. Although these have been raised from seed of the black currant, their gooseberry characteristics are recognised by both animal and vegetable parasites.

Another interesting hybrid spoken of was the result of a cross between the Clinton, an improved form of the native wild grape *Vitis cordifolia*, with Buckland's Sweetwater, a variety of *Vitis vinifera*. The Clinton produces a bunch which is small, long, and very compact, with a round black berry, quite acid. The Sweetwater forms a large loose bunch, and the berries are large, oval, and pale yellowish green. The hybrid produces large, rather loose, shouldered clusters with berries oval in form, and of a pale yellowish green colour. In size, form, colour, and quality the fruit resembles that of the male more than the female parent.

A number of varieties of dark purple raspberries have been produced by crossing the black cap raspberry, *Rubus occidentalis*, with one of the cultivated forms of the red raspberry, *Rubus strigosus*. The former is propagated by emitting roots from the tips of the pendulous branches when these touch the ground, while the latter sends up suckers from the running roots. The hybrids have usually rooted from the tips, but not freely, but in several instances occasional suckers have been sent up from the roots. The fruit has a flavour which is a striking combination of that of both parents.

Many crosses have been made during the past three years, using *Pyrus baccata* as female, the pollen being obtained from a number of different varieties of the most hardy Russian apples. *Pyrus baccata* has proved quite hardy on the north-west plains, where all the larger and better sorts of apples have failed, and this work has been undertaken with the object of securing useful fruits which will be hardy in the north-west country. With a similar object hybrids have also been obtained between the sand cherry, *Prunus pumila*, and the cultivated forms of the American plum, *Prunus americana*.

Some very promising varieties of wheat have been originated by crossing the Ladoga—a Russian sort—with Red and White Fife. One of these, known as Preston, ripens earlier than Red or White Fife, and in the tests made last season with a large number of varieties it stood first in productiveness.

Very distinct hybrids have been obtained between two-rowed and six-rowed barley, some of which are proving commercially valuable. Interesting results have also been had by crossing different sorts of oats; also different varieties of pease.

In ornamental shrubs striking hybrids have been produced between two species of barberry, *Berberis Thunbergii*, and *Berberis vulgaris purpurea*, combining the peculiarities of both parents in flowers, fruit, leaves, and general habit to a remarkable extent.

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4. *On a Hybrid Fern, with Remarks on Hybridity. By* Professor J. B. Farmer.

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5. *The Morphology of the Central Cylinder in Vascular Plants.* *By* E. C. Jeffrey.

There are three main types of fibro-vascular arrangement in plant axes, viz.—(1) a single so-called concentric aggregation; (2) several such aggregations, commonly, but not always, grouped in a circle; (3) a ring of so-called collateral or bicollateral bundles.

Disregarding the older views, Van Tieghem's is that the first type is primitive, and is to be designated monostelic; the second is derived from it by simple multiplication, and is consequently to be considered as polystelic; the last type is derived from the first by the segregation of a parenchymatous pith in the midst of the central vascular core, and the splitting of the resultant fibro-vascular ring into wedges called fibro-vascular bundles by radiating parenchymatous strands, the medullary rays. The last type of stem is according to this conception monostelic.

The writer considers that this view of the phenomena does not correspond with morphological facts. In some of the Pteridophyta we have a single vascular non-medullated axis from which originate the leaf-traces. This state of affairs is found, for example, commonly in the genera *Lycopodium* and *Selaginella.* In many ferns the stele becomes a tube just below the origin of the leaf-trace, and this cylinder breaks open again above the exit of the foliar bundle. This modification is seen in its simplest form in ferns with sparse leaves and creeping rhizomes, and the tubulisation of the stele seems to be a mechanical device to strengthen the slender axis, and to enable it to support its comparatively enormous leaves. Where the leaves are close ranked and the stem ascends the foliar gaps overlap, and the stelar cylinder becomes in a transverse section apparently a circle of separate bundles. In all such cases examined by Le Clerc du Sablon and the writer, the young stem has a tubular stele. Even when widely separated the vascular strands anastomose, so that there results a mechanically efficient fibro-vascular cylinder. In some genera, for example, *Antrophyum* and *Vittaria,* the internal bast of the stelar tube degenerates, the result being a state of affairs approximating that found in the Angiosperms with the exception that the pith freely communicates with the outside. This modification is very marked in certain Ophioglossaceæ and Lepidodendraceæ, which will be described at length in the fuller account which will appear shortly. In the former there is present sometimes an internal endodermis, although the internal bast has disappeared. Among the Gleicheniaceæ we have in *Mertensia* the cortex sending parenchymatous strands into the vascular axis of the stem down through the channelled leaf-traces; in *Gleichenia* and *Platyzoma* these are completely cut off from the outside cortex, and we find an entirely included pith similar to that presented by *Osmunda.* The pith of these forms is in reality extrastelar, but no longer communicates with the peripheral cortex.

We have a similar series in the Equisetaceæ, where in the young stem the vascular axis is not primitively dialydesmic, but gamodesmic, contrary to the statement of Van Tieghem. The primitive stelar arrangement is a closed tube with external and internal endodermic, but no internal bast. In the older stem this condition may be replaced by isolated bundles, surrounded by individual endodermal sheaths. Often, however, the primitive tube remains intact, and the internal endodermis disappears, bringing about a disposition quite similar to that obtaining in the higher plants. It is interesting to note that the *Calamiteæ* presented a still closer resemblance to the latter, owing to the presence of secondary wood.

The writer proposes for the stelar tube the term siphonostelic; where the internal as well as external bast is present, the stele is to be described as amphiphloic; where only the external bast is present, ectophloic. Monostelic axes are to be considered as protostelic, and present a marked contrast to the mechanically modified siphonostelic axes.

In the Filicales the siphonostelic modification arose in connection with the

support of large leaves, and hence is to be called phyllosiphonic. In the Lycopodiales, and probably the Equisetales, it is related to the support of branches, and hence may be termed cladosiphonic.

WEDNESDAY, AUGUST 25.

The following Papers were read:—

1. *The Gametophyte of* Botrychium virginianum. *By* Edward C. Jeffrey, *B.A.*

A complete description of the gametophyte of the Ophioglossaceæ has long been a desideratum.

Since the discovery by Mettinius, in 1856, of the subterranean prothallium of *Ophioglossum pedunculosum*, and by Hofmeister, in 1857, of that of *Botrychium lunaria*, nothing has been added till recently to their necessarily incomplete accounts of the gametophyte in these species. Our latest knowledge on this subject is derived from a brief description of incomplete material of the prothallium of *Botrychium virginianum* found in 1893 at Grosse Isle, Michigan, by Professor Douglas Campbell, which was published in the 'Proceedings' of the Oxford meeting of the British Association in 1894, p. 695.

During the summer of 1895 the writer secured a large number of prothallia of the same species at Little Metis in the Province of Quebec. On examination it was found that the material thus obtained afforded a complete elucidation of the development and structure of the antheridia and archegonia, and a less satisfactory series of stages in the segmentation of the embryo. Last summer the remaining prothallia were removed to the number of about six hundred; and, although they have only been partially studied, owing to technical difficulties in embedding them, yet those examined have supplied all the lacking stages of the development of the young sporophyte

It is proposed at the present time to furnish a brief account of the features of interest; a fuller description will shortly appear in the 'Transactions' of the Canadian Institute.

The gametophyte of *Botrychium virginianum* is of flattened oval shape, the narrower end of the prothallium being terminated by the growing point. My examples are from two to eighteen millimetres in length, by one and a-half to eight millimetres in breadth. Their thickness increases from the growing end backwards. The sides and lower surface of the prothallium are covered in younger specimens with multicellular hairs. In older plants these tend to disappear. The middle of the upper surface is occupied by a well-defined ridge, upon which the antheridia are situated. The archegonia are found on the declivities which slope away from the antheridial ridge.

As might be expected, the younger sexual organs are found nearer the growing point than those of greater age.

A cross section of the prothallium reveals to the naked eye the fact that the lower part of the gametophyte is composed of tissue which is yellowish in colour, and from which a thick oil exudes, even when the plant has been lying in 90 per cent. alcohol for months. The upper portion of the prothallium tissue, upon which the generative organs are situated, is white in colour and free from oil. A long section of the prothallium shows the same distribution of yellow oil-bearing and white oil-free tissue as the cross section, but demonstrates that the oil-bearing stratum is both absolutely and relatively much thicker in the older parts of the plant.

Microscopic examination shows that the oleiferous tissue has its cells occupied by an endophytic fungus and a very abundant protoplasm.

The fungus, so far as it has yet been studied, seems to be a sterile *Pythium*, possibly the same as that found by Treub, Goebel, and others in the prothallium

of species of *Lycopodium.* I hope to investigate the fungus more closely in a living condition during the next period of vegetation. The fungus filaments can be seen passing from the prothallium to the outside medium by way of the root-hairs.

The antheridia, as has been already stated, occur in numbers on a ridge running lengthwise on the upper surface of the prothallium. The young antheridia originate behind the growing point from a single superficial cell. This divides transversely the outer half, giving rise to the outer antheridial wall and the inner half by repeated simultaneous divisions to a large number of spermatocytes. The fully developed antheridium is largely embedded in the antheridial ridge, and projects only slightly above its surface. The formation of the spermatozoids has not yet been carefully studied, but seems to resemble closely that described in the Marattiaceæ and Equisetaceæ.

The spermatozoids are unusually large in size, but otherwise resemble the ordinary fern type, and consequently differ from the biciliate, moss-like spermatozoids of the Lycopodiales.

The archegonia are confined to the sloping sides of the upper surface of the prothallium. Unlike the antheridia, young archegonia, although most abundant near the growing point, may be formed on almost any part of the archegonia-bearing surface. The archegonium mother cell is superficial, and is distinguished from its neighbours by a larger nucleus and a more abundant protoplasm. It first divides transversely into a shallow outer cell and a deeper inner cell. The inner cell divides again, and as a result the young archegonium consists of three cells. The most external of these, by subsequent divisions, gives rise to the neck of the archegonium. The internal cell is the basal cell. It also divides into a plate of cells sometimes composed of two layers and distinguished by their richly protoplasmic contents. The middle cell of the young archegonium series gives rise by division to the neck canal cell and the ventral cell. The former becomes binucleate, but never divides into two cells. The latter, just before the maturation of the archegonium, divides into the egg-cell and the ventral canal cell. The ventral canal cell is broad, like that of the Marattiaceæ.

In the ripe archegonium the nuclei of the cells of the upper storeys of the archegonium neck become chromatolysed. I do not know yet whether this feature is peculiar to *Botrychium.*

The fully developed archegonium is sunk into the prothallium, and only the neck projects above its surface. The cervical cells are in four rows as in the other Pteridophyta, and the terminal ones spring apart when the egg is ripe.

Spermatozoids are frequently found in contact with the egg. After fertilisation the egg grows to many times its original size, and the reduced protoplasm contains a large hydroplastid.

The first division of the oospore is across the long axis of the archegonium. The next division is parallel with the long axis of the prothallium, and at right angles to the first. The third cross wall is in the transverse direction of the prothallium, and at right angles to the other two. I have been unable to follow satisfactorily the subsequent divisions.

The organs appear very late, and only after the embryo has attained a large size. The root is the first of them to emerge, and the proliferation of cells, indicating its place of origin, is long unmarked by the presence of an apical cell. The cotyledon, stem apex, and foot appear nearly simultaneously.

The root and cotyledon originate from the upper part of the embryonic mass; the foot and stem apex from its lower cells.

The apex of the root in many cases is in the same straight line with the canal of the archegonium neck.

It seems hardly possible to derive the organs from definite octants of the embryo.

The growth of the root ruptures the calyptra, and its exit is followed somewhat later by that of the cotyledon. The latter is not a bilaterally symmetrical structure, as in most ferns, but is of the same palmate type as is found in the

Osmundaceæ. The cotyledon begins to assimilate as soon as it reaches the surface of the ground, and thus resembles that of *Ophioglossum pedunculosum.*

There seems to be no evidence to indicate that more than the cotyledon appears above ground in the first season of the young plant's growth. In following summers apparently only a single leaf is produced, as is the case with the older plant. I have found young sporophytes, bearing their sixth leaf, still attached to the mother prothallium; and, as I have never found more than one leaf on the spore plants at once, and as the leaves, like other organs of this species of Botrychium, are extremely resistant to decay, I am reasonably certain that such examples were in the sixth year of their existence. This longevity of the gametophyte is of some interest.

One frequently finds two sporophytes on a single prothallium, and in many of these cases the apex of the prothallium is bifurcated. In one case I found two spore plants which had arisen from a single embryo. In another case I discovered two tracheids in a prothallium in the vicinity of a decayed young spore plant. The latter may have been of apogamous origin, as a similar phenomenon generally accompanies apogamy. I have not yet studied thoroughly the growing region of the prothallium, as it is best examined in longitudinal sections of the gametophyte. So far as I have investigated the matter, there seems to be evidence of the existence of an apical cell.

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2. *Remarks on Changes in number of Sporangia in Vascular Plants. By* F. O. Bower, *F.R.S.*

Comparison shows that in certain cases a progressive increase in number of sporangia has taken place, in others a decrease. The changes may be classified as follows:—

Increase in number of sporangia.

Directly
- (*a*) by septation of sporangia.
- (*b*) by interpolation of sporangia.

Indirectly
- (*c*) by continued apical or intercalary growth of the part bearing the sporangia, with or without branching.
- (*d*) by branchings in the non-sporangial region.

Decrease in number of sporangia.

Directly
- (*a*) by fusion of sporangia.
- (*b*) by abortion of sporangia.

Indirectly
- (*c*) by reduction or arrest of growth or branching of the part bearing the sporangia.
- (*d*) by suppression of branchings in the vegetative region, resulting in fewer sporangial shoots.

Probably this does not exhaust the list of modes of modification, but the condition of the individual plant, as we see it in the mature state, may be regarded as a resultant of modifications such as these, and the morphological problem will be in each case to assign the due importance to any or all such factors. The physiological condition of the plant during development may largely determine the greater or less prominence of any one factor.

An analytical study such as this may help in clearing the problem of the origin of homosporous Pteridophyta.

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3. *Notes on Fossil Equisetaceæ. By* A. C. Seward, *M.A., F.G.S., Cambridge.*

The genus *Equisetites,* established by Sternberg in 1838, has been used by several authors as a convenient designation for fossil Equisetaceous stems, which show a close agreement in external form with the recent Horse-tails. In the

absence of internal structure, and without a knowledge of details, it is better to adopt the term *Equisetites* than to include the fossils in the genus *Equisetum*.

In tracing the geological history of the Equisetaceæ it is extremely difficult to determine how far the evidence warrants the reference of certain Palæozoic fossils to *Equisetites* rather than to the genus *Calamites*. The fused leaf-segments usually regarded as characteristic of *Equisetites* may not be a trustworthy distinguishing feature. *Equisetites Hemingwayi*, Kidst, from the English Coal Measures, and other Permo-Carboniferous species, afford examples of the difficulties of correct determination. There are certain species of *Equisetites* of Mesozoic age which present characters of special interest, *e.g.*, *Equisetites Beanii*, *E. lateralis*, and others. An examination of several specimens of these forms has led to the conclusion that the specimens originally described as *Calamites Beanii*, and afterwards referred to the Monocotyledons, must be included in the genus *Equisetites*. *Equisetites Beanii*, from the Lower Oolite rocks of England, rivalled in size the gigantic Triassic stems described by Schimper and others from the Vosges Sandstones. *Equisetites lateralis*, regarded by some writers as a form of *Phyllotheca* or *Schizoneura*, is, in all probability, a true *Equisetites*, the reference to the former genera being founded on an incorrect interpretation of certain specimens. The so-called branch scars of *E. lateralis* are probably slightly displaced nodal diaphragms. In conclusion the author refers to specimens described as *Phyllotheca* from various localities and geological horizons, and expresses the opinion that in such cases the generic name *Equisetites* would be the more appropriate designation.

4. *On* Streptothrix actinomycotica *and allied species of* Streptothrix. *By* Professor E. M. Crookshank, *M.D.*

5. *Observations on the Cyanophyceæ.* *By* Professor A. B. Macallum, *Ph.D.*

6. *Report upon some Preliminary Experiments with the Röntgen Rays on Plants.* *By* George F. Atkinson.

The experiments were conducted for the purpose of testing the effect of the Röntgen rays on plants exposed during a considerable period of time.

Because of the numerous instances of reported injury to the human body as a result of exposure to the Röntgen rays, it has been suggested that it might also have an injurious influence on plants.

After a few preliminary experiments with leaves of Caladium, flowers of Begonia and seedlings of corn, wheat, sunflower, radish, german-millet, soja-bean, with exposures of one to ten hours, in which no perceptible injury resulted, a longer exposure was made, in which the following seedlings were acted on for a total of forty-five hours in a dark room: sunflower, wheat, german-millet, nonpareil-bean, soja-bean, cotton, oats, corn, vetch, pea, and cucumber. A duplicate set was placed also in the dark room, but outside the range of the Röntgen rays, as a check upon the experiment.

On some days a continuous run of fifteen hours was made. During this time the plants behaved exactly as plants grown in a dark room would. Some of the seedlings were at one time or another turned strongly towards the light, and at other times just as strongly away from it, and these movements were ascribed to nutation. At the close of the experiment all the growth which had taken place in the dark room was etiolated. On removing the seedlings from the dark room they all became slowly green, but the seedlings which were under the influence of the Röntgen rays recovered the green colour more slowly, which suggests that this light may have some slight injurious effect on the chloroplastids. No other influence of any kind was noted.

Another set of seedlings was then exposed for two days outside of the dark room. There was no perceptible influence.

The absorption of the Röntgen rays by the plants was then studied. Röntgen photographs of the seedlings experimented with, as well as of the internal structure of *Arisæma triphyllum, Pellandra virginica*, fruits of *Cycas, Podophyllum peltatum*, pea, bean, peach, plum, cherries, &c., and of the venation of leaves and internal parts of flowers were readily obtained; which shows that, while the rays penetrate plant tissues, they are also readily absorbed by the same. The lack of injuries or other influences then cannot be ascribed to non-absorption of the Röntgen rays.

Experiments were also made upon three species of Mucor, on several species of Bacteria, and on one species of Oscillatoria. No influence was exerted on the growth or movement of any of the plants experimented with.

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References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
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BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1897.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
§§ indicates Annual Subscribers who will be entitled to the Annual Report if their Subscriptions are paid by December 31, 1897.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics.*

Notice of changes of residence should be sent to the Assistant General Secretary, G. Griffith, Esq.

Year of Election.

1887. *Abbe, Professor Cleveland. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1897. §Abbott, A. H. Brockville, Ontario, Canada.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, Bart., K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., President of the Government Committee on Explosives. The Imperial Institute, Imperial Institute-road, and 2 Whitehall-court, S.W.
1885. *ABERDEEN, The Right Hon. the Earl of, G.C.M.G., LL.D., Governor-General of Canada. Ottawa.
1885. ‡Aberdeen, The Countess of. Ottawa.
1885. ‡Abernethy, David W. Ferryhill Cottage, Aberdeen.
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain W. DE W., R.E., C.B., D.C.L., F.R.S., F.R.A.S. Rathmore Lodge, Bolton-gardens South, Earl's Court, S.W.
1886. ‡Abraham, Harry. 147 High-street, Southampton.

Year of Election.

1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, S.W.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Woodmansterne Rectory, Banstead, Surrey.
1873. *Acland, Rev. H. D., M.A. Luccombe Rectory, Taunton.
1894. *Acland, Henry Dyke, F.G.S. The Old Bank, Great Malvern.
1873. *ACLAND, Sir HENRY W. D., Bart., K.C.B., M.A., M.D., LL.D., F.R.S. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 74 Brook-street, W.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L. Killerton, Exeter.
1887. ‡ADAMI, J. G., B.A. The University, Montreal, Canada.
1892. ‡Adams, David. Rockville, North Queensferry.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1871. §Adams, John R. 2 Nutley-terrace, Hampstead, N.W.
1879. *ADAMS, Rev. THOMAS, M.A., D.C.L., Canon of Quebec, Principal of Bishop's College, Lennoxville, Canada.
1869. *ADAMS, WILLIAM GRYLLS, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Campden Hill-square, W.
1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic in the University of Glasgow.
1896. §§Adamson, W. Sunnyside House, Prince's Park, Liverpool.
1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.
1890. ‡ADENEY, W. E., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
1865. *Adkins, Henry. Ley-hill, Northfield, near Birmingham.
1883. ‡Adshead, Samuel. School of Science, Macclesfield.
1896. §§Affleck, W. H. 28 Onslow-road, Fairfield, Liverpool.
1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
1887. ‡Agnew, William. Summer Hill, Pendleton, Manchester.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §AITKEN, JOHN, F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1884. *Alabaster, H. Lytton, Mulgrave-road, Sutton, Surrey.
1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1894. ‡Alexander, A. W. Blackwall Lodge, Halifax.
1891. ‡Alexander, D. T. Dynas Powis, Cardiff.
1883. ‡Alexander, George. Kildare-street Club, Dublin.
1888. *Alexander, Patrick Y. 47 Victoria-street, Westminster, S.W.
1873. ‡Alexander, R., M.D. 13 Hallfield-road, Bradford, Yorkshire.
1896. §§Alexander, William. 45 Highfield South, Rockferry, Chester.
1891. *Alford, Charles J., F.G.S. Coolivin, Hawkwood-road, Boscombe, Hants.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.

Year of Election.

1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. Sydenham Cottage, Park-lane, Sheffield.
1879. *Allen, Rev. A. J. C. The Librarian, Peterhouse, Cambridge.
1887. **Allen, Arthur Ackland. Overbrook, Kersal, Manchester.*
1887. **Allen, Charles Peter. Overbrook, Kersal, Manchester.*
1888. §Allen, F. J., M.A., M.B., Professor of Physiology, Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, S.W.
1887. ‡Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 28 Great Ormond-street, W.C.
1887. **Allen, Russell. 2 Parkwood, Victoria Park, Manchester.*
1891. ‡Allen, W. H. 24 Glenroy-street, Roath, Cardiff.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1889. §Allhusen, Frank E. The School, Harrow.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1886. ‡Allport, Samuel, F.G.S. Mason College, Birmingham.
1896. §§Alsop, J. W. 16 Bidston-road, Oxton.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. Care of Messrs. J. Evans & Co., Bute Docks, Cardiff.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid, Ashburton, Devon.
1884. §AMI, HENRY, M.A., F.G.S. Geological Survey, Ottawa, Canada.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Caius College, Cambridge.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, S.W.
1887. ‡Anderson, Professor R. J., M.D. Queen's College, Galway.
1889. ‡Anderson, R. Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *ANDERSON, TEMPEST, M.D., B.Sc., F.G.S. 17 Stonegate, York.
1886. *ANDERSON, Sir WILLIAM, K.C.B., D.C.L., F.R.S., M.Inst.C.E., Director-General of Royal Ordnance Factories. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1895. ‡Andrews, Charles W. British Museum (Natural History), S.W.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.
1896. §§Annett, R. C. F. 11 Greenhey-road, Liverpool.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1896. §§Appleton, C. 31A King-street, Wigan.
1894. §Archibald, A. Bank House, Ventnor.
1884. *Archibald, E. Douglas. Care of Mr. F. Tate, 28 Market-street, Melbourne, Australia.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S., F.R.S.E., F.G.S. Inverary.

Year of Election.

1883. §Armistead, Richard. 33 Chambres-road, Southport.
1883. *Armistead, William. Oakfield, Compton-road, Wolverhampton.
1887. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.
1857. *ARMSTRONG, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Cragside, Rothbury.
1879. *ARMSTRONG, Sir ALEXANDER, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Elms, Sutton Bonnington, Loughborough.
1886. ‡ARMSTRONG, GEORGE FREDERICK, M.A., F.R.S.E., F.G.S., Regius Professor of Engineering in the University of Edinburgh. The University, Edinburgh.
1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S., Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 55 Granville Park, Lewisham, S.E.
1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.
1889. ‡Armstrong, John A. 32 Eldon-street, Newcastle-upon-Tyne.
1884. ‡Armstrong, Robert B. Junior Carlton Club, Pall Mall, S.W.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1893. ‡Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.
1898. §ARROWSMITH, J. W. (LOCAL TREASURER). Bristol.
1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889.§§Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
ASHTON, THOMAS, J.P. Ford Bank, Didsbury, Manchester.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
1866. ‡Ashwell, Henry. Woodthorpe, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. Jackson. Hillside, Wilmslow, Cheshire.
1890. ‡Ashworth, J. Reginald, B.Sc. 105 Freehold-street, Rochdale.
1887. ‡Ashworth, John Wallwork, F.G.S. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Ashworth, Mrs. J. W. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. Tuplins, Newton Abbot.
1861.§§Asquith, J. R. Infirmary-street, Leeds.
1896. *Assheton, Richard. Birnam, Cambridge.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, W.C.
1896. §Atkin, George, J.P. Egerton Park, Rockferry.
1887. §Atkinson, Rev. C. Chetwynd, M.A. Fairfield House, Ashton-on-Mersey.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. ‡Atkinson, Edward, Ph.D., LL.D. Brookline, Massachusetts, U.S.A.
1894. §Atkinson, George M. 28 St. Oswald's-road, S.W.
1894. *Atkinson, Harold W. Erwood, Beckenham, Kent.
1861. ‡Atkinson, Rev. J. A. The Vicarage, Bolton.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡ATKINSON, ROBERT WILLIAM, F.C.S. 44 Loudoun-square, Cardiff.
1894. §Atkinson, William. Erwood, Beckenham, Kent.
1863. *ATTFIELD, J., M.A., Ph.D., F.R.S., F.C.S. 111 Temple-chambers, E.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. ‡Aulton, A. D., M.D. Walsall.

Year of Election.

1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, W.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 41 Kensington Park Gardens, W.

1884. ‡Baby, The Hon. G. Montreal, Canada.
1883. *Bach, Madame Henri. 12 Rue Fénélon, Lyons.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, N.W.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 114 Eaton-square, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892. ‡Baildon, H. Bellyse. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1855. ‡Bailey, W. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.
1894. *Baily, Francis Gibson, M.A. 11 Ramsay-garden, Edinburgh.
1878. ‡Baily, Walter. 4 Roslyn-hill, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James, M.P. 3 Park-terrace, Glasgow.
1897. §BAIN, JAMES, jun. Toronto.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, The Right Hon. G. W., M.P. 24, Addison Road, Kensington, W.
1894. ‡Balfour, Henry, M.A. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R S., F.R.S.E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.

Year of Election.

1890. ‡Bamford, Professor Harry, B.Sc. McGill University, Montreal, Canada.
1882. ‡Bance, Colonel Edward, J.P. Oak Mount, Highfield, Southampton.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1894. §Barclay, Arthur. 29 Gloucester-road, South Kensington, S.W.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, S.E.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. The Vicarage, Yatton, Bristol.
1870. ‡Barkly, Sir Henry, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, S.W.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. 53 Victoria-street, Westminster, S.W.
1889. §Barlow, H. W. L., M.A., M.B., F.C.S. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice. 5 Great George-street, Dublin.
1885. *Barlow, William, F.G.S. Hillfield, Muswell Hill, N.
1873. ‡Barlow, William Henry, F.R.S., M.Inst.C.E. High Combe, Old Charlton, Kent.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1895. ‡*Barr, James Mark. Central Technical College, E.C.*
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §§Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1872. *Barrett, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Abbotsgate, Huyton, near Liverpool.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.

Year of Election.

1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893. ‡Barrow, George, F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1896. §Barrowman, James. Stanacre, Hamilton, N.B.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡Barry, Right Rev. Alfred, D.D., D.C.L. The Cloisters, Windsor.
1862. *Barry, Charles. 1 Victoria-street, S.W.
1883. ‡Barry, Charles E. 1 Victoria-street, S.W.
1875. ‡Barry, Sir John Wolfe, K.C.B., F.R.S., Pres.Inst.C.E. 23 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, G. C. T., M.P. St. Margaret's House, Victoria-street, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. ‡Barton, Edwin H., B.Sc. University College, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. ‡Bassano, Alexander. 12 Montagu-place, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, N.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8a Manchester-square, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡Bateman, A. E., C.M.G., Controller General, Statistical Department. Board of Trade, 7 Whitehall Gardens, S.W.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡Bateson, William, M.A., F.R.S. St. John's College, Cambridge.
1881. *Bather, Francis Arthur, M.A., F.G.S. 135 Kensington High-street, W.; and British Museum (Natural History), S.W.
1836. ‡Batten, Edmund Chisholm. Thorn Falcon, near Taunton, Somerset.

Year of
Election.

1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §Bayly, F. W. 8 Royal Mint, E.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S. 61 Grosvenor-street, W.
1882. §Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. Oxford.
1889. §Beare, Prof. T. Hudson, F.R.S.E., M.Inst.C.E. University College, W.C.
1887. ‡*Beaton, John, M.A. 219 Upper Brook-street, Chorlton-on-Medlock, Manchester.*
1842. *Beatson, William. Ash Mount, Rotherham.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. Post Office, Knutsford, Cheshire.
1885. *BEAUMONT, W. W., M.Inst.C.E., F.G.S. Outer Temple, 222 Strand, W.C.
1896. §§Beazer, C. Hindley, near Wigan.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, S.W.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hill House, Buxton, Derbyshire.
1885. §§BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1896. §Bedford, F. S. King's College, Cambridge.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. *Belinfante, L. L., B.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884 ‡Bell, Charles Napier. Winnipeg, Canada.
1896. §BELL, DUGALD, F.G.S. 27 Lansdowne-crescent, Glasgow.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. 35 Cambridge-street, Hyde Park, W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.

Year of Election.

1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. Howell Hill Lodge, Ewell, Surrey.
1896. §§Bell, James. 38 Russian-drive, Stoneycroft, Liverpool.
1891. ‡Bell, James. Bangor Villa, Clive-road, Cardiff.
1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡*Bell, R. Bruce, M.Inst.C.E. 203 St. Vincent-street, Glasgow.*
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1893. ‡BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc. The Museum, Oxford.
1891. §§Bennett, Alfred Rosling. 44 Manor Park-road, Harlesden, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, N.W.
1896. §§Bennett, George W. West Ridge, Oxton.
1836. ‡Bennett, Henry. Bedminster, Bristol.
1881. §Bennett, John Ryan. 3 Upper Belgrave-road, Clifton, Bristol.
1883. *Bennett, Laurence Henry. The Hall, East Ilsley, Berkshire.
1896. §§Bennett, Richard. 19 Brunswick-street, Liverpool.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Stellenbosch, South Africa.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1897. §Bently, R. R. 97 Dowling-avenue, Toronto, Canada.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §Berkeley, The Right Hon. the Earl of. Foxcombe, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, Sir HENRY, F.R.S. Denmark Hill, S.E.
1882. *Bessemer, Henry, jun. Town Hill Park, West End, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. 55 Gunterstone-road, W.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1890. §Bevington, Miss Mary E. Merle Wood, Sevenoaks, Kent.
1870. ‡Bickerton, A.W. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. The Zoological Station, Naples.
1885. *BIDWELL, SHELFORD, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, S.E.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.

Year of Election.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. West Lea, Ranmoor, Sheffield.
1881. ‡Binnie, Sir Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1880. ‡Bird, Henry, F.C.S. South Down House, Millbrook, near Devonport.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, London, W.
1887. *Birley, H. K. Hospital, Chorley, Lancashire.
1871. *Bischof, Gustav. 19 Ladbroke-gardens, W.
1892. ‡*Bishop, Arthur W., Ph.D. Heriot Watt College, Edinburgh.*
1894. ‡Bisset, James. 5 East India-avenue, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Major W. H. Custom House, Cincinnati, Ohio, U.S.A.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889. ‡Black, William. 12 Romulus-terrace, Gateshead.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 1 Belhaven-terrace, Kelvinside, Glasgow.
1896. §Blackie, Walter W., B.Sc. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1896. §§Blackwood, J. M. 16 Oil-street, Liverpool.
1895. ‡Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1888. ‡Blaine, R. S., J.P. Summerhill Park, Bath.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, W.
1886. ‡*Blake, Dr. James. San Francisco, California.*
1883. *Blake, Rev. J. F., M.A., F.G.S. 69 Comeragh-road, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, S.E.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1894. ‡Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1887. ‡Blamires, George. Cleckheaton.
1881. ‡Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1895. §§Blamires, William. Oak House, Taylor Hill, Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, W.
1887. *Bles, A. J. S. Palm House, Higher Broughton, Manchester.
1887. *Bles, Edward J., B.Sc. Newnham Lea, Grange-road, Cambridge.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1880. ‡Bloxam, G. W., M.A. 11 Presburg-street, Clapton, N.E.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.

Year of Election.

1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡Blyth, James, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
1883. ‡Blyth, Miss Phœbe. 27 Mansion House-road, Edinburgh.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1876. ‡Bolton, J. C. Carbrook, Stirling.
1894. §Bolton, John. Clifton-road, Crouch End, N.
1898. §Bonar, J., M.A., LL.D., 1 Redington-road, Hampstead, N.W.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, N.W.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, N.W.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Charles, F.S.S. 2 Talbot-court, Gracechurch-street, E.C.
1883. §Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, W.C.
1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, S.W.
1883. ‡Boothroyd, Benjamin. Solihull, Birmingham.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S. Tenerife.
1896. §§Bose, Dr. J. C. Calcutta, India.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Otterwood, Beaconsfield-road, Weston-super-Mare.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *Bottomley, James Thomson, M.A., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany, King's College, W.C.
1876. ‡Bottomley, William, jun. 15 University-gardens, Glasgow.
1890. §Boulnois, Henry Percy, M.Inst.C.E. Municipal Offices, Liverpool.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, S.W.
1883. ‡Bourne, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.
1893. §Bourne, G. C., M.A., F.L.S. Savile House, Mansfield-road, Oxford.
1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, Chiswick.
1866. §§Bourne, Stephen, F.S.S. 5 Lansdown-road, Lee, S.E.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.

Year of Election.

1884. §BOVEY, HENRY T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1881. *BOWER, F. O., D.Sc., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E. Mayfield, Knutsford, Cheshire.
1887. §Box, Alfred Marshall. 68 Huntingdon-road, Cambridge.
1895. *BOYCE, RUBERT, M.B., Professor of Pathology, University College, Liverpool.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S. 27 The Grove, Boltons, S.W.
1872. *BRABROOK, E. W., C.B., F.S.A. 178 Bedford-hill, Balham, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.
1864. ‡BRAHAM, PHILIP. 3 Cobden-mansions, Stockwell-road, S.E.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. The Rectory, Dickleburgh.
1885. *Bratby, William, J.P. Oakfield Hale, Altrincham, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. Goldsmith-buildings, Temple, E.C.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡Brice, Arthur Montefiore, F.G.S., F.R.G.S. 159 Strand, W.C.
1886. §§Bridge, T. W., M.A., D.Sc., Professor of Zoology in the Mason Science College, Birmingham.
1870. *Bridson, Joseph R. Bryerswood, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN, M.P. Kildwick Hall, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, Keighley, Yorkshire.
1893. ‡Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, S.W.
1893. §§Briscoe, Albert E., A.R.C.Sc., B.Sc. Battersea Polytechnic, S.W.

Year of Election.

1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. *Brittain, W. H., J.P., F.R.G.S. Alma Works, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Blackheath, S.E.
1897. §Brock, W. R. Toronto.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1859. *Brodhurst, Bernard Edward, F.R.C.S. 20 Grosvenor-street, Grosvenor-square, W.
1883. *Brodie, David, M.D. 12 Patten-road, Wandsworth Common, S.W.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. The Gore, Eastbourne.
1881.§§Brook, Robert G. Wolverhampton House, St. Helens, Lancashire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1888. ‡Brooke, Rev. Canon R. E., M.A. 14 Marlborough-buildings, Bath.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1887. *Bros, W. Law. Camera Club, Charing-cross-road, W.C.
1883. *Brotherton, E. A. Arthington Hall, viâ Leeds.
1883. *Brough, Mrs. Charles S. Rosendale Hall, West Dulwich, S.E.
1886.§§Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 29 Wheeley's-road, Birmingham.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1896.§§Brown, A. T. The Nunnery, St. Michael's Hamlet, Liverpool.
1867. ‡Brown, Sir Charles Gage, M.D., K.C.M.G. 88 Sloane-street, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1883. ‡Brown, Mrs. H. Bienz. 62 Stanley-street, Aberdeen.
1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.
1870. §Brown, Horace T., F.R.S., F.C.S., F.G.S. 52 Nevern-square, S.W.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. Canaan-grove, Newbattle-terrace, Edinburgh.
1895. ‡Brown, J. Allen, J.P., F.R.G.S., F.G.S. 7 Kent-gardens, Ealing, W.
1870. *Brown, Professor J. Campbell, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. 7 Second-avenue, Sherwood Rise, Nottingham.
1895. *Brown, John Charles. 7 Second-avenue, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D. Haddington, N.B.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
1882. *Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.

Year of Election.

1897. §Brown, Price, M.B. 37 Carlton-street, Toronto, Canada.
1886. §Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1897. §Brown, Richard. Jarvis-street, Toronto, Canada.
1896.§§Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §Brown, T. Forster, M.Inst.C.E., F.G.S. Guild Hall Chambers, Cardiff.
1865. ‡Brown, William. 41a New-street, Birmingham.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1892. ‡Browne, Harold Crichton. Crindon, Dumfries.
1895. *Browne, Henry Taylor. 10 Hyde Park-terrace, W.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1891.§§Browne, Montagu, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Sandbrook, Tullow, Co. Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1887. ‡Brownell, T. W. 6 St. James's-square, Manchester.
1865. ‡Browning, John, F.R.A.S. 63 Strand, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1893. ‡Bruce, William S. University Hall, Riddle's-court, Edinburgh.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, I. 15 Devonshire-terrace, W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1896. *Brunner, Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡Brunton, T. Lauder, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1878. §Brutton, Joseph. Yeovil.
1886. *Bryan, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894.§§Bryan, Mrs. R. P. Thornlea, Trumpington-road, Cambridge.
1884. ‡Bryce, Rev. Professor George. Winnipeg, Canada.
1897. §Bryce, Right Hon. James, D.C.L., M.P., F.R.S. 54 Portland-place, W.
1894. ‡Brydone, R. M. Petworth, Sussex.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §Buchan, Alexander, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡Buchanan, John Young, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, W.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1865. *Buckley, Henry. 18 Princes-street, Cavendish-square, W.
1886. §Buckley, Samuel. Merlewood, Beaver Park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, W.C.

Year of Election.

1851. *Buckton, George Bowdler, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Penryn, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §Bulleid, Arthur. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, S.W.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Thackray. 'Journal' Office, New-street, Birmingham.
1895. ‡Bunte, Dr. Hans. Karlsruhe, Baden.
1886. §Burbury, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. §§Burke, John. Owens College, Manchester.
1884. *Burland, Lieut.-Col. Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, G.C.S.I., C.I.E., F.R.G.S. 132 Sutherland-gardens, Maida Vale, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, E.C.
1883. *Burrows, Abraham. Russell House, Rhyl, North Wales.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1894. ‡Burstall, H. F. W. 76 King's-road, Camden-road, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, W.
1894. ‡Burton, Charles V. 24 Wimpole-street, W.
1866. *Burton, Frederick M., F.L.S., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1897. §Burton, S. H., M.B. 50 St. Giles's-street, Norwich.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, W.
1897. §Burwash, Rev. N., LL.D., Principal of Victoria University, Toronto, Canada.
1887. *Bury, Henry. Trinity College, Cambridge.
1895. §Bushe, Colonel C. K., F.G.S. Bramhope, Old Charlton, Kent.
1878. ‡Butcher, J. G., M.A. 22 Collingham-place, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, S.W.

Year of Election.

1872. ‡Buxton, Sir Thomas Fowell, Bart., K.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth-park, Liverpool.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1894. ‡Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1886. **Caldwell, William Hay. Cambridge.*
1868. ‡Caley, A. J. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1887. ‡CALLAWAY, CHARLES, M.A., D.Sc., F.G.S. 35 Huskisson-street, Liverpool.
1897. §CALLENDER, Professor HUGH L., F.R.S. 62 Hutchinson-street, Montreal, Canada.
1892. ‡Calvert, A. F., F.R.G.S. Royston, Eton-avenue, N.W.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Sir Charles, Bart., M.D., LL.D. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, Sir CHARLES A., M.D. 15 Pembroke-road, Dublin.
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1897. §Campbell, Major J. C. L. New Club, Edinburgh.
1897. §Campion, B. W. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡Cannan, Edwin, M.A., F.S.S. 24 St. Giles's, Oxford.
1897. §Cannon, Herbert. Erith, Kent.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.
1894. §Capper, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1880. ‡Capper, Robert. 18 Parliament-street, Westminster, S.W.
1883. ‡Capper, Mrs. R. 18 Parliament-street, Westminster, S.W.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, W.
1896. *Carden, H. V. Lismore, Lovelace-gardens, Surbiton.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1867. ‡Carmichael, David (Engineer). Dundee.
1897. §Carmichael, Norman R. Queen's University, Kingston, Ontario, Canada.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1897. §Carpenter, R. C. Cornell University, Ithaca, New York, U.S.A.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.

Year of Election.

1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. ‡Carr, J. Wesley, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. 14 Vermont-road, Norwood.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1883. ‡Carson, John. 51 Royal-avenue, Belfast.
1837. *Carson, Rev. Joseph, D.D., M.R.I.A. 1 Trinity College, Dublin.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
1897. §Carter, E. Tremlett. Broadclyst, 53 Cloudesdale-road, S.W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1896. §Cartwright, Miss Edith G. 69 Gloucester-road, Kew, Surrey.
1878. *Cartwright, Ernest H., M.A., M.D. 1 Courtfield-gardens, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I., Borough and Water Engineer. Albion-place, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1894. ‡Carus, Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1896. *Casey, James. 10 Philpot-lane, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1897. §Caston, Harry Edmonds Featherston. 340 Brunswick-avenue, Toronto, Canada.
1888. ‡Cater, R. B. Avondale, Henrietta Park, Bath.
1874. ‡Caton, Richard, M.D. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Devonshire House, New Malden, Surrey.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡Chambers, Mrs. Colâba Observatory, Bombay.
1883. ‡Chambers, Charles, Assoc.M.Inst.C.E. Colâba Observatory, Bombay.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Abchurch-chambers, E.C.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 1 Grand Avenue, Brighton.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1897. §Chapman, Edward Henry. 17 St. Hilda's-terrace, Whitby.

Year of Election.

1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. ‡Chapman, T. Algernon, M.D. 17 Wesley-avenue, Liscard, Cheshire.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡Charnock, Richard Stephen, Ph.D., F.S.A. Crichton Club, Adelphi-terrace, W.C.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, S.W.
1886. §Chattock, A. P. University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡Chauveau, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 19 Portman-street, Portman-square, W.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1896. §§Chenie, John. Charlotte-street, Edinburgh.
1874. *Chermside, Colonel Sir H. C., R.E., K.C.M.G., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1896. §§Cherry, R. B. 92 Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1889. ‡Chirney, J. W. Morpeth.
1894. ‡Chisholm, G. G., M.A., B.Sc., F.R.G.S. 26 Dornton-road, Balham, S.W
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *Chree, Charles, D.Sc., F.R.S., Superintendent of the Kew Observatory, Richmond, Surrey.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 3 Tankerville-road, Streatham, London, S.W.
1876. *Chrystal, George, M.A., LL.D., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §Church, A. H., M.A., F.R.S., F.C.S., Professor of Chemistry to the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, E.C.
1896. §Clague, Daniel, F.G.S. 5 Sandstone-road, Stoneycroft, Liverpool.
1890. ‡Clark, E. K. 13 Wellclose-place, Leeds.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
Clark, George T. 44 Berkeley-square, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. §Clark, James, M.A., Ph.D., Professor of Agriculture in the Yorkshire College, Leeds.
1892. ‡Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc. 12 Feversham-terrace, York.
1861. ‡Clark, Latimer, F.R.S., F.R.A.S., M.Inst.C.E. 11 Victoria-street, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.

Year of Election.

1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1887. §Clarke, C. Goddard, J.P. Fairlawn, 157 Peckham-rye, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. §§Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1897. §Clarke, Colonel S. C. Uphill, Guildford.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1896. §Clarke, W. W. Albert Dock Office, Liverpool.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. §CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1886. ‡*Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.*
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1893. ‡Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 38 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S. London County Council, London.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne, James. Rubislaw Den South, Aberdeen.
1891. *Coates, Henry. Pitcullen House, Perth.
1897. §Coates, J., M.Inst.C.E. 99 Queen-street, Melbourne, Australia.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. Westfield, Ilkley, Yorkshire.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, S.W.
1896. *Coghill, Percy de G. Camster, Cressington.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1894. *Colby, Miss E. L. Carreg-wen, Aberystwith.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby, William Henry. Carreg-wen, Aberystwith.
1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.
1893. ‡Cole, Grenville A. J., F.G.S. Royal College of Science, Dublin.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1894. ‡Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, S.W.
1897. §Coleman, Dr. A. P. 476 Huron-street, Toronto, Canada.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, W.

Year of Election.

1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1892. §§Collie, Alexander. Harlaw House, Inverurie.
1887. ‡Collie, J. Norman, Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 16 Campden-grove, W.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. ‡Collinge, Walter E. Mason College, Birmingham.
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 69 Great Russell-street, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡Collins, J. H., F.G.S. 162 Barry-road, S.E.
1892. ‡Colman, H. G. Mason College, Birmingham.
1868. *Colman, J. J. Carrow House, Norwich.
1882. †Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 17 Victoria-street, S.W.
1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, S.W.
1897. §Colquhoun, A. H. W., B.A. 39 Borden-street, Toronto, Canada.
1896. *Comber, Thomas. Leighton, Parkgate, Chester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡Common, A. A., LL.D., F.R.S., Pres.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1891. ‡Common, J. F. F. 21 Park-place, Cardiff.
1892. ‡Comyns, Frank, M.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1896. §§Connacher, W. S. Birkenhead Institute, Birkenhead.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1881. ‡Conroy, Sir John, Bart., M.A., F.R.S. Balliol College, Oxford.
1893. ‡Conway, Sir W. M., M.A., F.R.G.S. The Red House, Hornton-street, W.
1876. ‡*Cook, James. 162 North-street, Glasgow.*
1882. ‡Cooke, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, S.W.
1876. *Cooke, Conrad W. 28 Victoria-street, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1895. §§Cooke, Miss Janette E. Holmwood, Thorpe, Norwich.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1896. §§Cookson, E. H. Kiln Hey, West Derby.
1888. †Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.
1895. ‡Cooper, Charles Friend, M.I.E.E. 68 Victoria-street, Westminster, S.W.
1893. ‡Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡Cooper, George B. 67 Great Russell-street, W.C.
1868. ‡Cooper, W. J. New Malden, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. †Copeland, Ralph, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.

Year of Election.

1885. ‡Copland, W., M.A. Tortorston, Peterhead, N.B.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1842. Corbett, Edward. Grange-avenue, Levenshulme, Manchester.
1891. §Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 9 Alwyne-square, N.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1881. §Cordeaux, John. Great Cotes House, R.S.O., Lincoln.
1883. *Core, Professor Thomas H., M.A. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College, London. 19 Savile-row, W.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡Cornish, Vaughan. Ivy Cottage, Newcastle, Staffordshire.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 12 Beaufort-buildings East, Bath.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, W.C.
1891. *Cotsworth, Haldane Gwilt. G.W.R. Laboratory, Swindon, Wilts.
1874. *COTTERILL, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1879. ‡Cottrill, Gilbert I. Shepton Mallet, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, S.W.
1896. ‡COURTNEY, Right Hon. LEONARD, M.P. 15 Cheyne Walk, Chelsea, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
1896. §§Coventry, J. 19 Sweeting-street, Liverpool.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 31 Belsize Park-gardens, N.W.
1895. *COWELL, PHILIP H. Royal Observatory, Greenwich, S.E.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. ‡Crabtree, William. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. 66 Edge-lane, Liverpool.
1884. §CRAIGIE, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.

Year of Election.

1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. ‡Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T. LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Edinburgh.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.
1885. §CREAK, Captain E. W., R.N., F.R.S. 7 Hervey-road, Blackheath, S.E.
1896. §Cregeen, A. C. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. §Crewe, W. Outram. 121 Bedford-street, Liverpool.
1896. §Crichton, H. 6 Rockfield-road, Anfield, Liverpool.
1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. University College, Stephen's Green, Dublin.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. ‡*Crompton, A. 1 St. James's-square, Manchester.*
1887.§§CROOK, HENRY T. 9 Albert-square, Manchester.
1865. §CROOKES, Sir W., F.R.S., V.P.C.S. (PRESIDENT ELECT.) 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *Crookshank, E. M., M.B., Professor of Bacteriology in King's College, London, W.C.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. Annesley, Aigburth, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1887.§§Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A., F.G.S. Halecote, Grange-over-Sands.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1894.§§Crow, C. F. Home Lea, Woodstock-road, Oxford.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry. Bramley Oaks, Croydon.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.

Year of Election.

1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *CULVERWELL, EDWARD P., M.A. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1897. §Cumberland, Barlow. Toronto, Canada.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in Trinity College, Dublin.
1891. ‡Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1892. ‡*Cunningham, Very Rev. John. St. Bernard's College, Edinburgh.*
1885. ‡CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., F.G.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. WILLIAM, D.D., D.Sc. Trinity College, Cambridge.
1892. §Cunningham-Craig, E. H., B.A., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1892. *Currie, James, jun., M.A. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, S.W.

1889. ‡Dagger, John H., F.I.C. Victoria Villa, Lorne-street, Fairfield, Liverpool.
1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1889. *Dale, Miss Elizabeth. Westbourne, Buxton, Derbyshire.
1863. ‡Dale, J. B. South Shields.
1867. ‡Dalgleish, W. Dundee.
1894. ‡Dalgleish, W. Scott, M.A., LL.D. 25 Mayfield-terrace, Edinburgh.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. ‡Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, W.
1897. §Darbishire, C. W. Darbishire Granite Quarries, Penmaenmawr.
1897. §Darbishire, F. V. Rossplatz 12I, Leipzig.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A. 26 George-street, Manchester.

Year of Election.

1896. §Darbishire, W. A. Penybryn, Carnarvon, North Wales.
1882. ‡DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1894. §DARWIN, Major LEONARD, Sec. R.G.S. 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., M.A., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 1 Cavendish-crescent, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.
1880. *DAVEY, HENRY, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1887.§§Davies, David. 55 Berkley-street, Liverpool.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1893. *Davies, Rev. T. Witton, B.A. Midland Baptist College, Nottingham.
1896. *Davies, W. V. 41 Park-place, Cardiff.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 13 St. Ermin's-mansions, S.W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1842. Davis, Rev. David, B.A. Almswood, Evesham.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1896. *Davis, John Henry Grant. 18 Clare-road, Halifax, Yorkshire.
1883. ‡Davis, R. Frederick, M.A. Earlsfield, Wandsworth Common, S.W.
1885. *Davis, Rev. Rudolf. 1 Victoria-avenue, Evesham.
1891. ‡Davis, W. 48 Richmond-road, Cardiff.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, M.A. 16 Manor-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, E. W., M.D. Kimmage Lodge, Roundtown, Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.S.A., F.G.S., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1897. §DAWSON, G. M., C.M.G., LL.D., F.R.S., Director of the Geological Survey of Canada. Ottawa, Canada.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington, Burnsall, Skipton.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. §DAWSON, Sir WILLIAM, C.M.G., M.A., LL.D., F.R.S., F.G.S. 293 University-street, Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, T. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, S.W.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.

Year of Election.

1861. ‡Dean, Henry. Colne, Lancashire.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S. 4 Schlangenweg, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. §§Deeley, R. M. 10 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1870. ‡De Meschin, Thomas, B.A., LL.D. 15 Sandycove-avenue West, Dublin.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1897. §Denison, F. Napier. The Observatory, Toronto, Canada.
1896. ‡Denison, Miss Louisa E. 16 Chesham-place, S.W.
1889. §Denny, Alfred, F.L.S., Professor of Biology in University College, Sheffield.
Dent, William Yerbury. 5 Caithness-road, Brook Green, W.
1874. §De Rance, Charles E., F.G.S. 55 Stoke-road, Shelton, Stoke-upon-Trent.
1896. §§Derby, The Right Hon. the Earl of, G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 63 Queensborough-terrace, W.
1878. ‡*De Rinzy, James Harward. Khelat Survey, Sukkur, India.*
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1868. ‡Dewar, James, M.A., LL.D., F.R.S., F.R.S.E., Pres.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Rugby School, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, W.
1887. ‡De Winton, Major-General Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. United Service Club, Pall Mall, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *Dew-Smith, A. G., M.A. Trinity College, Cambridge.
1896. §§D'Hemry, P. 136 Prince's-road, Liverpool.
1897. §Dick, D. B. Toronto, Canada.
1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.
1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund, M.A., F.G.S. 11 West Cliff-road, Birkdale, Southport.
1887. §Dickson, H. N., F.R.S.E. 2 St. Margaret's-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., F.R.G.S. 76 Sloane-street, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1884. ‡Dix, John William H. Bristol.
1874. *Dixon, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.

Year of Election.

1888. §Dixon, Edward T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, S.W.
1886. ‡Dixon, George. 42 Augustus-road, Edgbaston, Birmingham.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1896. §Dixon-Nuttall, F. R. Ingleholme, Ecclestone Park, Prescot.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne-park, W.
1897. §Doberck, William. The Observatory, Hong Kong.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1893. ‡Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1894. ‡Dockar-Drysdale, Mrs. 39 Belsize-park, N.W.
1875. *Docwra, George, jun. 108 London-road, Gloucester.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1897. §Dodge, Richard E. Teachers' College, Morningside Heights, New York, U.S.A.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1893. ‡Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, M.Inst.C.E. The Mount, Wray Park, Reigate.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1896.§§Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. South Kensington Museum, S.W.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Henwick, Newbury.
1877. *DOUGLASS, Sir JAMES N., F.R.S., M.Inst.C.E. Stella House, Bonchurch, Isle of Wight.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1894. ‡Dowie, Robert Chambers. 13 Carter-street, Higher Broughton, Manchester.
1884. *Dowling, D. J. Bromley, Kent.
1857. ‡*Downing, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.*
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. 3 Great Queen-street, S.W.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. ‡Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡DRESSER, HENRY E., F.Z.S. 110 Cannon-street, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.

Year of Election.

1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, W.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1895. *Duddell, William. 47 Hans-place, S.W.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., F.R.G.S. 11 Chelsea-embankment, S.W.
1852. ‡DUFFERIN AND AVA, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, W.
1883.§§Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, S.W.
1866. *Duncan, James. 9 Mincing-lane, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡Duncan, William S. 143 Queen's-road, Bayswater, W.
1896.§§Duncanson, Thomas. 16 Deane-road, Liverpool.
1881. ‡Duncombe, The Hon. Cecil, F.G.S. Nawton Grange, York.
1893. *Dunell, George Robert. 9 Grove Park-terrace, Chiswick, Middlesex.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1896.§§Dunkerley, S. University Engineering Laboratory, Cambridge.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. Northern Polytechnic Institute, Holloway-road, N.
1883. ‡Dunn, Mrs. Northern Polytechnic Institute, Holloway-road, N.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University Station, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1893. *Dunstan, M. J. R. Newcastle-circus, Nottingham.
1891. ‡Dunstan, Mrs. Newcastle-circus, Nottingham.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Scientific Department of the Imperial Institute, S.W.
1869. ‡D'Urban, W. S. M., F.L.S. Moorlands, Exmouth, Devon.
1895. *Dwerryhouse, Arthur R. 65 Louis-street, Leeds.
1887. ‡*Dyason, John Sanford. Boscobel-gardens, N.W.*
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Bletchley.
1895. §Dymond. Thomas S., F.C.S. County Technical Laboratory, Chelmsford.
1897. §Dynan, Miss. 75 Queen's-park, Toronto, Canada.

Year of Election.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. §§Earle, Hardman A. 29 Queen Anne's-gate, Westminster, S.W.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1888. ‡Earson, H. W. P. 11 Alexandra-road, Clifton, Bristol.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON, EDWARD. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. §Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1887. *Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 6 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J., F.G.S. Silchar, Cachar, India.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. The College House, Leamington.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, E.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 29 Dover-street, Piccadilly, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B., F.G.S. 1 Garden-court, Temple, E.C.
1867. *Edward, Allan. Farington Hall, Dundee.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1896. §Ekkert, Miss Dorothea. 95 Upper Parliament-street, Liverpool.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 113 Cannon-street, E.C.
1885. ‡Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1886. ‡Elliott, Thomas Henry, C.B., F.S.S. Board of Agriculture, 4 Whitehall-place, S.W.
1877. ‡Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, W.
1880. *ELLIS, JOHN HENRY. Woodland House, Plymouth.
1891. §Ellis, Miss M. A. 2 Southwick-place, W.
1884. ‡Ellis, Professor W. Hodgson, M.A., M.B. 74 St. Alban's-street, Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, W.C.

Year of Election.

1897. §Elvery, Mrs. Elizabeth. The Cedars, Maison Dieu-road, Dover.
1883. ‡Elwes, Captain George Robert. Bossington, Bournemouth.
1887. §ELWORTHY, FREDERICK T. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1897. §Ely, Robert E. Cambridge, Massachusetts, U.S.A.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1891. ‡Emerton, Wolseley. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1890. ‡Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.
1894. ‡Emtage, W. T. A. University College, Nottingham.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, E. Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Enys, Penryn, Cornwall.
1894. §Erskine-Murray, James. 46 Great King-street, Edinburgh.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins Hey, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Hayesleigh, Montague-road, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 20 Albert-square, Manchester.
1869. ‡ETHERIDGE, R., F.R.S., F.R.S.E., F.G.S. 14 Carlyle-square, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, S.W.
1883. ‡Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *Evans, A. H. Care of R. H. Porter, 18 Prince's-street, W.
1887. *Evans, Mrs. Alfred W. A. Lyndhurst, Upper Chorlton-road, Whalley Range, Manchester.
1870. *EVANS, ARTHUR JOHN, M.A., F.S.A. Youlbury, Abingdon.
1865. *EVANS, Rev. CHARLES, M.A. 41 Lancaster-gate, W.
1896. §Evans, Edward, jun. Spital Old Hall, Bromborough, Cheshire.
1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1884. ‡Evans, Horace L. 6 Albert-buildings, Weston-super-Mare.
1883. *Evans, James C. 175 Lord-street, Southport.
1883. *Evans, Mrs. James C. 175 Lord-street, Southport.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., Treas.R.S., F.S.A., F.L.S., F.G.S. (PRESIDENT). Nash Mills, Hemel Hempstead.
1897. *Evans, Lady. Nash Mills, Hemel Hempstead.
1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡Evans, William Llewellin. Guildhall-chambers, Cardiff.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. University College, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S., F.R.S.E., Derryvolgie-avenue, Belfast.
1895. §Everett, W. H., B.A. University College, Nottingham.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.

Year of Election.

1890. †Fletcher, B. Morley. 7 Victoria-street, S.W.
1892. ‡Fletcher, George, F.G.S. 60 Connaught-avenue, Plymouth.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 36 Woodville-road, Ealing, W.
1862. §FLOWER, Sir WILLIAM HENRY, K.C.B., LL.D., D.C.L., D.Sc., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Departments, British Museum, South Kensington, S.W. 26 Stanhope-gardens, S.W.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1877. *Floyer, Ernest A. Downton, Salisbury.
1890. *Flux, A. W., M.A. Owens College, Manchester.
1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1891. §Foldvary, William. Museum Ring, 10, Buda Pesth.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1880. ‡Foote, R. Bruce, F.G.S. Care of Messrs. H. S. King & Co., 65 Cornhill, E.C.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.
1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1897. §Forbes, J., Q.C. Hazeldean, Putney-hill, S.W.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. ‡FORD, J. RAWLINSON. Quarry Dene, Weetwood-lane, Leeds.
1875 *FORDHAM, H. GEORGE. Odsey, Ashwell, Baldock, Herts.
1883.§§Formby, R. Kirklake Bank, Formby, near Liverpool.
1894.§§Forrest, Frederick. Castledown, Castle Hill, Hastings.
1887. ‡FORREST, The Right Hon. Sir JOHN, K.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
1883. ‡FORSYTH, A. R., M.A., D.Sc., F.R.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1882. ‡Forward, Henry. 10 Marine-avenue, Southend.
1896.§§FORWOOD, Sir WILLIAM B., J.P. Ramleh, Blundellsands, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, S.W.
1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 18 Daleham-gardens, Hampstead, N.W.
1896.§§Foster, Miss Harriet. Cambridge Training College, Wollaston-road, Cambridge.
1877. §Foster, Joseph B. 4 Cambridge-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., LL.D., D.C.L., Sec.R.S., F.L.S., Professor of Physiology in the University of Cambridge. Great Shelford, Cambridge.
1863. ‡Foster, Robert. The Quarries, Grainger Park-road, Newcastle-upon-Tyne.
1896. ‡Fowkes, F. Hawkshead, Ambleside.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1892. ‡Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, E.C.

Year of Election.

1876. **Fowler, John.* 16 *Kerrsland-street, Hillhead, Glasgow.*
1882. ‡FOWLER, Sir JOHN, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. 104 Ritherdon-road, Upper Tooting, S.W.
1883. §Fox, Sir CHARLES DOUGLAS, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.
1896.§§Fox, Henry J. Bank's Dale, Bromborough, near Liverpool.
1883. ‡Fox, Howard, F.G.S. Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1888. ‡Fox, Thomas. Court, Wellington, Somerset.
1886. ‡*Foxwell, Arthur, M.A., M.B.* 17 *Temple-row, Birmingham.*
1881. *FOXWELL, HERBERT S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, E.C.; and Manor House, Richmond, Surrey.
1845. ‡FRANKLAND, Sir EDWARD, K.C.B., M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S., Professor of Chemistry and Metallurgy in the Mason College, Birmingham.
1894. §Franklin, Mrs. E. L. 9 Pembridge-gardens, W.
1895.§§Fraser, Alexander. 63 Church-street, Inverness.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1897. §Fraser, Sir Malcolm, K.C.M.G. 15 Victoria-street, S.W.
1871. ‡FRASER, THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. Rowmore House, Garelochhead, N.B.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. 12 Buckingham Palace-gardens, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., F.R.G.S. 1 Airlie-gardens, Campden Hill, W
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. ‡Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1892. *Frost, Edmund. Chesterfield, Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. ‡Frost, Major H., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 53 Victoria-road, W.
1898. §FRY, The Right Hon. Sir EDWARD, D.C.L., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 13 Upper Belgrave-road, Clifton, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1895. ‡Fullarton, Dr. J. H. Fishery Board for Scotland, George-street, Edinburgh.

Year of Election.

1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1896.§§Gilmour, H. B. Underlea, Aigburth, Liverpool.
1892. *Gilmour, Matthew A. B. Saffronhall House, Windmill-road, Hamilton, N.B.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham.
1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1886. *Gisborne, Hartley. Qu'Appelle StationP.O., Assa.,N.-W.T., Canada.
1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., F.R.S., F.C.S. 17 Pembridge-square, W.
1883. *Gladstone, Miss. 17 Pembridge-square, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. The Shola, Heathfield-road, South Croydon.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.
1897. §Glashan, J. C. Ottawa, Canada.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S. 7 Harvey-road, Cambridge.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
1859. ‡Glennie, J. S. Stuart, M.A. Verandah Cottage, Haslemere, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
1874. ‡Glover, George T. Corby, Hoylake.
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1889. ‡Goddard, F. R. 19 Victoria-square, Newcastle-upon-Tyne.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1886. ‡Godlee, Arthur. The Lea, Harborne, Birmingham.
1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.
1878. *Godlee, J. Lister. 3 Clarence-terrace, Regent's-park, N.W.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
1890. *GONNER, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. 1038 Rookery Building, Chicago, Illinois, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1883. ‡*Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.*
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.

Year of Election.

1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. 8 St. Mary-street, St. Andrews, N.B.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. ‡Gordon, William John. 3 Lavender-gardens, S.W.
1865. ‡Gore, George, LL.D., F.R.S. 67 Broad-street, Birmingham.
1875. *Gotch, Francis, M.A., B.Sc., F.R.S., Professor of Physiology in the University of Oxford, The Lawn, Banbury-road, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1894. ‡Gould, G. M., M.D. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1875. ‡Grahame, James. 12 St. Vincent-street, Glasgow.
1892. §Grange, C. Ernest. 57 Berners-street, Ipswich.
1893. ‡Granger, Professor F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. §Grant, Sir James, K.C.M.G. Ottawa, Canada.
1892. ‡Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F., F.G.S. Northumberland-chambers, Northumberland-avenue, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. ‡Gray, Professor Andrew, M.A., LL.D., F.R.S., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1865. ‡Gray, Charles. Swan Bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1893. ‡Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.
1870. ‡Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. *Gray, James H., M.A., B.Sc. The University, Glasgow.
1892. §Gray, John, B.Sc. 351 Coldharbour-lane, Brixton, S.W.
1887. ‡Gray, Joseph W., F.G.S. Cleveland Villa, Shurdington Road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Gray, Mrs. W. L. Westmoor Hall, Brimsdown, Middlesex.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, N.W.

Year of Election.

1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. ‡Hannaford, E. P. 2573 St. Catherine-street, Montreal, Canada.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
1886. §Hansford, Charles, J.P. 3 Alexandra-terrace, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. 6 Queen Anne's-gate, S.W.
1886. *Hardcastle, Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1892. *Harden, Arthur, Ph.D., M.Sc. 20 Kensington-crescent, W.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrook House, Exeter.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1894. ‡Hardman, S. C. 225 Lord-street, Southport.
1897. §HARDY, Hon. ARTHUR S., Premier of the Province of Ontario. Toronto, Canada.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1838. *HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §HARKER, ALFRED, M.A., F.G.S. St. John's College, Cambridge.
1896. §§Harker, Dr. John Allen. Springfield House, Stockport.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W., M.D. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 1 Belmont, Tenby.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest Hill, S.E.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest Hill, S.E.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.
1888. ‡Harris, C. T. 4 Kilburn Priory, N.W.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1884. ‡*Harris, Miss Katherine E. 73 Albert Hall-mansions, S.W.*
1888. ‡Harrison, Charles. 20 Lennox-gardens, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡Harrison, George. Barnsley, Yorkshire.

Year of Election.

1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *Harrison, J. Park, M.A. 22 Connaught-street, Hyde Park, W.
1892. ‡Harrison, John. Rockville, Napier-road, Edinburgh.
1889. §Harrison, J. C. Oxford House, Castle-road, Scarborough.
1870. ‡Harrison, Reginald, F.R.C.S. 6 Lower Berkeley-street, Portman-square, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsay, Isle of Man.
1895. §§Harrison, Thomas. 48 High-street, Ipswich.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *Hartland, E. Sidney, F.S.A. Highgarth, Gloucester.
1897. §Hartley, E. G. S. Wheaton Astley Hall, Stafford.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
1896. §§Hartley, W. P., J.P. Aintree, Liverpool.
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡Hartog, P. J., B.Sc. Owens College, Manchester.
1897. §Harvey, Arthur. Rosedale, Toronto, Canada.
1885. §§Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1882. ‡Haslam, George James, M.D. Owens College, Manchester.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1875. *Hastings, G. W. 23 Kensington-square, W.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, S.W.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, E.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. 2 Down-street, W., and 33 Great George-street, S.W.
1897. §Hawksley, Charles. 60 Porchester-terrace, W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. ‡Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *Hay, Admiral the Right Hon. Sir John C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E., Professor of Physiology, University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1894. ‡Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1896. §Hayes, Rev. F. C. The Rectory, Raheny, Dublin.
1896. §Hayes, William. Fernyhurst, Rathgar, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1858. *Hayward, R. B., M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1896. *Haywood, A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rock Ferry.
1851. §Head, Jeremiah, M.Inst.C.E., F.C.S. 47 Victoria-street, Westminster, S.W.

Year of Election.

1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in Mason Science College. 16 Duchess-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stokeleigh, Leigh Woods, Clifton, Bristol.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1886. ‡Hingley, Sir Benjamin, Bart. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, Sir WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1890. *Hirst, James Andus. Adel Tower, Leeds.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1881. §Hobbes, Robert George, M.R.I. Livingstone House, 374 Wandsworth-road, S.W.
1879. ‡Hobkirk, Charles P., F.L.S. Hill House, Park-road, Dewsbury.
1887. *Hobson, Bernard, B.Sc., F.G.S. Tapton Elms, Sheffield.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. ‡Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1896. §§Hodgkinson, Arnold. 16 Albert-road, Southport.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 8 Park-villas, Blackheath, S.E.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1896. §§Hodgson, Dr. Wm., J.P. Helensville, Crewe.
1894. §§Hogg, A. F. 4 Cliffe-terrace, Darlington.
1894. §§Holah, Ernest. 5 Crown-court, Cheapside, E.C.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1887. *Holder, Henry William, M.A. Owens College, Manchester.
1896. §§Holder, Thomas. 2 Tithebarn-street, Liverpool.

Year of Election

1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. ‡Holgate, Benjamin, F.G.S. Cardigan Villa, Grove-lane, Headingley, Leeds.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, S.E.
1896. §§Holland, Mrs. Hooton.
*_Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, N.W._
1889. ‡Holländer, Bernard. King's College, Strand, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 24 Aberdare-gardens, West Hampstead, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1896. §§Holt, William Henry. 11 Ashville-road, Birkenhead.
1897. §Holterman, R. F. Brantford, Ontario, Canada.
1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡HOOKER, Sir JOSEPH DALTON, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.
1892. §§Hooker, Reginald H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Rutford-road, Streatham, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Holy Trinity Vicarage, Blackheath Hill, Greenwich, S.E.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. 14 Airlie-gardens, Campden Hill, W.
1884. *_Hopkins, Edward M. Orchard Dene, Henley-on-Thames._
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *HOPKINSON, CHARLES. The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1870. *HOPKINSON, JOHN, M.A., D.Sc., F.R.S. Holmwood, Wimbledon, Surrey.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 34 Margaret-street, Cavendish-square, W.; and The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.
Hornby, Hugh. Sandown, Liverpool.
1885. ‡HORNE, JOHN, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1875. *Horniman, F. J., M.P., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, S.E.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, VICTOR A. H., B.Sc., F.R.S., F.R.C.S. 25 Cavendish-square, W.
1884. *Hotblack, G. S. Brimdall, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S. St. John's College, Cambridge.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1896. §§Hoult, J. South Castle-street, Liverpool.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
1893. ‡Howard, F. T., M.A., F.G.S. University College, Cardiff.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.

Year of Election.

1886. *Howard, James L., D.Sc. 86 St. John's-road, Waterloo, near Liverpool.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1885. ‡Howden, James C., M.D. Sunnyside, Montrose, N.B.
1889. §Howden, Robert, M.B., Professor of Anatomy in the University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Great Britain. Geological Survey Office, Edinburgh.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1891. §§Howell, Rev. William Charles, M.A., Vicar of Holy Trinity, High Cross, Tottenham, Middlesex.
1886. §Howes, Professor G. B., F.R.S., F.L.S. Royal College of Science, South Kensington, S.W.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, Sir H. H., K.C.I.E., M.P., D.C.L., F.R.S., F.S.A. Bentcliffe, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §Hoyle, William E., M.A. Owens College, Manchester.
1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1888. ‡Hudson, C. T., M.A., LL.D., F.R.S. 2 Barton-crescent, Dawlish.
1894. §Hudson, John E. 125 Milk-street, Boston, Massachusetts, U.S.A.
1867. *Hudson, William H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, S.W.
1858. *Huggins, Sir William, K.C.B., D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. 90 Upper Tulse Hill, S.W.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. §Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1896. §§Hughes, John W. New Heys, Allerton, Liverpool.
1870. *Hughes, Lewis. Fenwick-chambers, Liverpool.
1891. ‡Hughes, Thomas, F.C.S. 31 Loudoun-square, Cardiff.
1868. §Hughes, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge. 18 Hills-road, Cambridge.
1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the City of Birmingham. Birmingham.
1867. §Hull, Edward, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens, Notting Hill, W.
*Hulse, Sir Edward, Bart., D.C.L. Breamore House, Salisbury.
1897. §Hume, J. G., M.A., Ph.D. 650 Church-street, Toronto, Canada.
1887. *Hummel, Professor J. J. 152 Woodsley-road, Leeds.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, S.W.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1877. *Hunt, Arthur Roope, M.A., F.G.S. Southwood, Torquay.

Year of
Election.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-garden Cardiff.
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael. Greystones, Sheffield.
1879. ‡HUNTINGTON, A. K., F.C.S., Prof. of Metallurgy in King's College, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *HURST, CHARLES HERBERT, Ph.D. Royal College of Science, Dublin.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1896. *Hurter, Dr. Ferdinand. Holly Lodge, Cressington, Liverpool.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Major E. R., R.E. 24 Waterloo-place, Southampton.
1894. *Hutchinson, A. Pembroke College, Cambridge.
1896. §Hutchinson, W. B. 144 Sussex-road, Southport.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
1883. §Idris, T. H. W. 58 Lady Margaret-road, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. ‡Ingle, Herbert. Pool, Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1892. ‡Ireland, D. W. 10 South Gray-street, Edinburgh.
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §§IRVING, Rev. A., B.A., D.Sc., F.G.S. Hockerill, Bishop Stortford, Herts.
1888. *Isaac, J. F. V., B.A. Royal York Hotel, Brighton.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, W.
1891. *ISMAY, THOMAS H. 10 Water-street, Liverpool.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

Year of
Election.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *Jackson, Professor A. H., B.Sc. 358 Collins-street, Melbourne, Australia.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1874. *Jackson, Frederick Arthur. Penalva Ranche, Millarville, Alberta, Calgary, N.W.T., Canada.
1883. *Jackson, F. J. Harefield, 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. Harefield, 1 Morley-road, Southport.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1897. §Jackson, James. 34 Lonsdale-square, N.
1869. §Jackson, Moses, J.P. 139 Lower Addiscombe-road, Croydon.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. Villa Jaffe, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. 6 New-court, Lincoln's Inn, W.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡James, John. 24 The Parade, Cardiff.
1891. ‡James, John Herbert. Howard House, Arundel-street, Strand, W.C.
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1896. §James, O. S. 192 Jarvis-street, Toronto, Canada.
1858. ‡James, William C. Woodside, Plymouth.
1896. *Jameson, H. Lyster. Killencoole, Castlebellingham, Ireland.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §Jamieson, G. Auldjo. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *Japp, F. R., M.A., LL.D., F.R.S., F.C.S., Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, W.
1887. §§Jeffs, Osmund W. 164 Falkner-street, Liverpool.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1891. ‡Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. Royal College of Science, South Kensington, S.W.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, S.W.
1880. *Jenkins, Sir John Jones, M.P. The Grange, Swansea.
1852. ‡Jennings, Francis M., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Ashleigh, Ashleigh-road, Leicester.
1897. §Jennings, W. T. 34 St. Vincent-street, Toronto, Canada.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
1887. §Jervis-Smith, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.

Year of Election.

Jessop, William, jun. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1891. ‡John, E. Cowbridge, Cardiff.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §JOHNSON, ALEXANDER, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 1 Victoria-road, Clapham Common, S.W.
1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. ‡Johnson, J. G. Southwood Court, Highgate, N.
1875. ‡Johnson, James Henry, F.G.S. 73 Albert-road, Southport.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *JOHNSON, THOMAS, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, Sir H. H., K.C.B., F.R.G.S. Queen Anne's Mansions, S.W.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S., St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1896. *Joly, C. J., M.A. The Observatory, Dunsink, Co. Dublin.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S. 39 Waterloo-road, Dublin.
1881. ‡Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.
1997. §Jones, D., J.P., F.G S. Kilsal Hall, Shifnal, Shropshire.
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. 7 Marine-terrace, Aberystwith.
1891. ‡Jones, D. Edgar, M.D. Spring Bank, Queen-street, Cardiff.
1890. §Jones, Rev. Edward, F.G.S. 7 Fairfax-road, Prestwich, Lancashire.
1891. ‡Jones, Dr. Evan. Aberdare.
1896. §§Jones, E. Taylor. University College, Bangor.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, Waterloo, Liverpool.
1895. ‡Jones, Harry. Engineer's Office, Great Eastern Railway, Ipswich.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, N.W.

Year of Election.

1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, S.W.
1881. *JONES, J. VIRIAMU, M.A., B.Sc., F.R.S., Principal of the University College of South Wales and Monmouthshire, Cardiff.
1897. §Jones, Robert, M.D. London County Lunatic Asylum, Claybury, Woodford Bridge, Essex.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 17 Parson's Green, Fulham, S.W.
1896. §Jones, W. Hope Bank, Lancaster-road, Pendleton, Manchester.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡Jones, William Lester. 22 Newport-road, Cardiff.
1875. *Jose, J. E. 49 Whitechapel, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1879. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1896.§§Joyce, Joshua. 151 Walton-street, Oxford.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. *Jubb, Abraham. Halifax.
1870. ‡JUDD, JOHN WESLEY, C.B., F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 22 Cumberland-road, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, N.
1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1859. ‡Kay, David, F.R.G.S. 78 Warwick-gardens, Kensington, W.
1887. ‡*Kay, Miss. Hamerlaund, Broughton Park, Manchester.*
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1894. ‡Keene, Captain C. T. P., F.Z.S. 11 Queen's-gate, S.W.
1894 §§Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.
1892. ‡Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.
1887. ‡*Kellas-Johnstone, J. F. 35 Crescent, Salford.*
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1885. §KELTIE, J. SCOTT, LL.D. Sec. R.G.S., F.S.S. 1 Savile-row, W.
1847. *KELVIN, The Right Hon. Lord, G.C.V.O., M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. The University, Glasgow.
1877. *Kelvin, Lady. The University, Glasgow.
1887. ‡Kemp, Harry. 254 Stretford-road, Manchester.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, 17 Arundel-road, Eastbourne.
1891.§§KENDALL, PERCY F., F.G.S., Professor of Geology in Yorkshire College, Leeds.

Year of Election.

1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E. 17 Victoria-street, S.W., and 1 Queen Anne-street, Cavendish-square, W.
1897. §Kennedy, George, LL.D. Crown Lands Department, Toronto, Canada.
1884. §Kennedy, George T., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1897. §Kenrick, Frank B Knesebeckstr. 3iii., Charlottenburg, Berlin.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893.§§Kent, A. F. Stanley, F.G.S. St. Thomas's Hospital, S.E.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1886. §KENWARD, JAMES, F.S.A. 43 Streatham High-road, S.W.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡KERMODE, PHILIP M. C. Ramsey, Isle of Man.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡KERR, REV. JOHN, LL.D., F.R.S. Free Church Training College, Glasgow.
1892. ‡Kerr, J. Graham. Christ's College, Cambridge.
1889. ‡Kerry, W. H. R. Wheatlands, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Rose Villa, Vale-road, Bowdon, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §KIDSTON, ROBERT, F.R.S.E., F.G.S. 24 Victoria-place, Stirling.
1897. §Kiekelly, Dr. John, LL.D. 46 Upper Mount-street, Dublin.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Dublin.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Stonelands, East Grinstead.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, N.W.
1883. *King, Joseph, jun. Lower Birtley, Witley, Godalming.
1860. *King, Mervyn Kersteman. 3 Clifton-park, Clifton, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889.§§King, Sir William. Stratford Lodge, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1897. §Kingsmill, Nichol. Toronto, Canada.

Year of Election.

1875. §KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst, Kent.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1897. §Kirkland, Thomas. 432 Jarvis-street, Toronto, Canada.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1886.§§Klein, Rev. L. M. de Beaumont, D.Sc., F.L.S. 6 Devonshire-road, Liverpool.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. McK., F.G.S. Bushwood, Wanstead, Essex.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Aingarth, Stalybridge, Cheshire.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1897. §Knowlton, W. H. 36 King-street East, Toronto, Canada.
1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1892. ‡KOHN, CHARLES A., Ph.D. University College, Liverpool.
1890. *Krauss, John Samuel, B.A. Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 111 Church-street, Chelsea, S.W.
1897. §Laird, Professor G. J. Wesley College, Winnipeg, Canada.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Old Lodge, Salisbury.
1887. ‡LAMB, HORACE, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, S.E.
1896. §Lambert, Frederick Samuel. Balgowan, Newland, Lincoln.
1893. ‡Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893. ‡Lamplugh, G. W., F.G.S. Geological Survey Office, Jermyn-street, S.W.
1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, S.E.

Year of Election.

1883. ‡Lang, Rev. Gavin. Mayfield, Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 2 Bradmore-road, Oxford.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Physiography in the Mason Science College, Birmingham. 13 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. The Moat, Harrow.
1896. *Last, William J. South Kensington Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. 5 Pepy's-road, Wimbledon, Surrey.
1891. ‡Laurie, A. P. 49 Beaumont-square, E.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, E.C.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, S.W.
1884. §Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York
1889. §Laws, W. G., M.Inst.C.E. 65 Osborne-road, Newcastle-upon-Tyne.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1888. §§Layard, Miss Nina F. 2 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, S.W.
1894. *Leahy, A. H., M.A., Professor of Mathematics in Firth College; 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. **Leatham, Edward Aldam. 46 Eaton-square, S.W.*
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1895. *Ledger, Rev. Edmund. Barham Rectory, Claydon, Ipswich.
1898 §LEE, ARTHUR. (LOCAL SECRETARY) 12 Richmond-hill, Clifton, Bristol.
1861. ‡Lee, Henry. Sedgeley Park, Manchester.
1896. §Lee, Rev. H. J. Barton. South Park View, Ashburton, Devon.
1891. §Lee, Mark. The Cedars, Llandaff-road, Cardiff.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.

Year of
Election.

1896. *Leech, Lady. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1892. *LEES, CHARLES H., M.Sc. Coningsby Villa, Wellington-road, Fallowfield, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1896.§§Lees, William. 10 Norfolk-street, Manchester.
1883. *Leese, Miss H. K. 3 Lord-street West, Southport.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW. 18 Bryanston-square, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. ‡Lehfeldt, Robert A. Firth College, Sheffield.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1890. ‡Leigh, Marshall. 22 Goldsmid-road, Brighton.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 38 Portland-place, W.
1871. ‡LEONARD, HUGH, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. 51 Arcade-chambers, St. Mary's Gate, Manchester.
1883.§§Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. §Lever, W. H. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. ‡Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, S.W.
1893. *Lewes, Vivian B., F.C.S.. Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, Professor D. Morgan, M.A. University College, Aberystwith.
1897. §Lewis, Rev. J. Pitt. Rossin House, Toronto, Canada.
1891. ‡Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1860. ‡LIDDELL, The Very Rev. H. G., D.D. Ascot, Berkshire.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
*LIMERICK, The Right Rev. CHARLES GRAVES, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1878. ‡Lincolne, William. Ely, Cambridgeshire.

Year of Election.

1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1883. ‡Lisle, H. Claud. Nantwich.
1895. §Lister, The Right Hon. Lord, D.C.L., Pres.R.S. 12 Park-crescent, Portland-place, W.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex, N.E.
1861. *Liveing, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *Liversidge, Archibald, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W.
1864.§§Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡Llewelyn, Sir John T. D., Bart., M.P. Penllegare, Swansea.
1889. ‡Lloyd, Rev. Canon. The Vicarage, Rye Hill, Newcastle-upon-Tyne.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
1886. ‡Lloyd, J. Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt., M A., F.R.S.E. 49a Grove-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1897. §Lloyd-Verney, J. H. 14 Hinde-street, Manchester-square, W.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Woodgreen, Wednesbury.
1854. *Lobley, James Logan, F.G.S. City of London College, Moorgate-street, E.C.
1892. §Loch, C. S., B.A. 15a Buckingham-street, W.C.
1867. *Locke, John. 33 Duke-street Chambers, W.C
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡Lockyer, Sir J. Norman, K.C.B., F.R.S., F.R.A.S. Royal College of Science, South Kensington, S.W.
1886. *Lodge, Alfred, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *Lodge, Oliver J., D.Sc., LL.D., F.R.S., Professor of Physics in University College, Liverpool. 2 Grove-park, Liverpool.
1894. *Lodge, Oliver W. F. 2 Grove-park, Liverpool.
1889. ‡Logan, William. Langley Park, Durham.
1896.§§Lomas, J. 16 Mellor-road, Birkenhead.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.
1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. 1 Brewer-street, Oxford.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Brown House, Blawith, *viâ* Ulverston.
1861. *Lord, Edward. Adamroyd, Todmorden.
1894. ‡Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, U.S.A.
1889. ‡Lord, Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.
1897. §Loudon, James, LL.D., President of the University of Toronto, Canada.

Year of Election.

1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §§Louis, Henry, Professor of Mining, Durham College of Science, Newcastle-on-Tyne.
1887. *Love, A. E. H., M.A., F.R.S. St. John's College, Cambridge.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. 29 Park-crescent, Monkgate, York.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡Low, Charles W. 84 Westbourne-terrace, W.
1867. *Low, James F. Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Cardiff.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.
1886. *Lowe, John Landor, M.Inst.C.E. The Birches, Burton-road, Derby.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1894. ‡Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.
1897. §Lowry, George. Manchester.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Farnborough, R.S.O., Kent.
1853. *Lubbock, The Right Hon. Sir John, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, R.S.O., Kent.
1881. ‡Lubbock, John B. 14 Berkeley-street, W.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, S.W.
1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1897. §Lumsden, George E., F.R.A.S. 57 Elm-avenue, Toronto, Canada.
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Coal Mining in Yorkshire College, Leeds. 6 De Grey-road, Leeds.
1874. *Lupton, Sydney, M.A. A. Audley-mansions, 44 Mount-street, W.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. ‡Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1896. §Lyster, A. G. Dockyard, Coburg Dock, Liverpool.
1896. §§Lyster, George F. Plas Isaf, Ruthin.
1862. *Lyte, F. Maxwell, F.C.S. 60 Finborough-road, S.W.

1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.

Year of Election.

1876. *Macadam, William Ivison, F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.A., M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MacAlister, Donald, M.A., M.D., B.Sc. St. John's College, Cambridge.
1896. §§Macalister, N. A. S. 2 Gordon-street, W.C.
1896. §Macallum, Professor A. B., Ph.D. The University, Toronto.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander. 79 Holland Park, W.
1896. §§McArthur, Charles. Villa Marina, New Brighton, Chester.
1884. ‡Macarthur, D. Winnipeg, Canada.
1896. *Macaulay, F. S., M.A 19 Dewhurst-road, W.
1834. Macaulay, James, A.M., M.D. 25 Carlton-vale, N.W.
1896. §§MacBride, Professor E. W., M.A. McGill University, Montreal, Canada.
1897. §McAllister, Samuel. 99 Wilcox-street, Toronto, Canada.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1891. *McClean, Frank, M.A., LL.D., F.R.S., M.Inst.C.E. Rusthall House, Tunbridge Wells.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'Clintock, Admiral Sir Francis L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, S.W.
1872. *McClure, J. H., F.R.G.S. Whiston, Prescot.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1892. *McCowan, John, M.A., D.Sc. University College, Dundee.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn Fields, W.C.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1897. §McEwen, William C. 9 South Charlotte-street, Edinburgh.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1897. §McFarlane, Murray, M.D. 32 Carlton-street, Toronto, Canada.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1897. §McGaw, Thomas. Queen's Hotel, Toronto, Canada.
1888. ‡MacGeorge, James. 67 Marloes-road, Kensington, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. Dunavon, Westmount, Montreal, Canada.

Year of Election.

1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1885. ‡Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buchanan-street, Hillhead, Glasgow.
1867. *M'Intosh, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. §Mackay, A. H., LL.D. Education Office, Halifax, Nova Scotia, Canada.
1885. §Mackay, John Yule, M.D., Professor of Anatomy in University College, Dundee
1897. §McKay, T. W. G., M.D. Ottawa, Ontario, Canada.
1896. *McKechnie, Duncan. Eccleston Grange, Preston.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Glasgow. 2 Florentine-gardens, Glasgow.
1883. ‡McKendrick, Mrs. 2 Florentine Gardens, Glasgow.
1897. §McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.
1872. *Mackey, J. A. 175 Grange-road, S.E.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. ‡Mackinder, H. J., M.A., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1891. ‡Mackintosh, A. C. Temple Chambers, Cardiff.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1896. §§Maclagan, Miss Christian. Ravenscroft, Stirling.
1892. ‡Maclagan, Sir Douglas, M.D., LL.D., F.R.S.E., Professor of Medical Jurisprudence in the University of Edinburgh. 28 Heriot-row, Edinburgh.
1892. ‡Maclagan, Philip R. D. St. Catherine's, Liberton, Midlothian.
1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent Edinburgh.
1873. ‡McLandsborough, John, F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1897. §MacLaren, J. F. 380 Victoria-street, Toronto, Canada.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1897. §MacLaren. Rev. Wm., D.D. 57 St. George-street, Toronto, Canada.
1882. ‡Maclean, Inspector-General, C. B. 1 Rockstone-terrace, Southampton
1892. *Maclean, Magnus, M.A., F.R.S.E. The University, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLeod, Herbert, F.R.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.

Year of
Election.

1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Lieut.-General C. A., F.G.S. 20 Nevern-square, South Kensington, S.W.
1883. ‡MacMahon, Major P. A., R.A., F.R.S., Professor of Electricity in the Artillery College, Woolwich. 52 Shaftesbury-avenue, W.C.
1878. *M'Master, George, M.A., J.P. Rathmines, Ireland.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡McMurrick, J. Playfair. University of Michigan, Ann Arbor, Michigan, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, A. W. Care of Messrs. Maconochi eBros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
*Macrory, Edmund, M.A. 19 Pembridge-square, W.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip. B.Sc. 16 Gloucester-terrace, Hyde Park, W.
1896. §§Maguire, Thomas Philip. Eastfield, Lodge-lane, Liverpool.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. The Admiralty, Whitehall, S.W.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1885. *Maitland, Sir James R. G., Bart., F.G.S. Stirling, N.B.
1883. ‡Maitland, P. C. 136 Great Portland-street, W.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
1887. ‡Manchester, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1885. ‡Mann, George. 72 Bon Accord-street, Aberdeen.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1894. §Manning, Percy, M.A., F.S.A. Watford, Herts.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C., F.G.S. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1889. ‡*Manville, E. 3 Prince's-mansions, Victoria-street, S.W.*
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. ‡Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡Markham, Sir Clements R., K.C.B., F.R.S., Pres.R.G.S., F.S.A. 21 Eccleston-square, S.W.
1894. ‡Markoff, Dr. Anatolius. 44 Museum-street, W.C.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.

Year of Election.

1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, J. E., M.A., F.R.S., Sec.G.S. St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. Hurstwood, Roundhay, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. 131 Warrender Park-road, Edinburgh.
1881. *Marshall, John, F.R.A.S. 2 Strattan-street, Leeds.
1890. ‡Marshall, John. Derwent Island, Keswick.
1881. ‡Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1884. §Martin, N. H., F.L.S. 8 Windsor-crescent, Newcastle-upon-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.
1890. §Martindale, William. 19 Devonshire-street, Portland-place, W.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, W.C.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1883. ‡Marwick, Sir James, LL.D. Killermont, Maryhill, Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S. Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1896. §§Mason, Philip B., F.L.S., F.Z.S. Burton-on-Trent.
1893. *Mason, Thomas. 6 Pelham-road, Sherwood Rise, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1894. ‡MATHEWS, Prof. G. B., M.A., F.R.S. Bangor.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, W.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 21 Augustus-road, Edgbaston, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡MATTHEWS, JAMES. Springhill, Aberdeen.

Year of
Election.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1893. ‡Mavor, Professor James, M.A., LL.D. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Hiram S. 18 Queen's Gate-place, Kensington, S.W.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1887. ‡Maxwell, James. 29 Princess-street, Manchester.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1897. §Mecredy, James, M.A. Wynberg, Stradbrook, Blackrock, Dublin.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1867. ‡MELDRUM, CHARLES, C.M.G., LL.D., F.R.S., F.R.A.S. 25 South-parade, Southsea.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1896. §Mellor, G. H. Weston, Blundell Sands, Liverpool.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1896. §§Menneer, R. R. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, E.C.
1879. §MERIVALE, JOHN HERMAN, M.A. Togston Hall, Acklington.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1896. §Metzler, W. H., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S., Professor of Biology in the Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 15 Grange-road, West Hartlepool.
1894. *MIERS, H. A., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. ‡MILES, MORRIS. Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., F.R.S.E., Librarian R.G.S. 109 West End-lane, Hampstead, N.W.

Year of
Election.

1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1892. *Millard, William Joseph Kelson, M.D., F.R.G.S. Holmleigh, Rockleaze, Stoke Bishop, Bristol.
1882. ‡*Miller, A. J. 15 East Park-terrace, Southampton.*
1875. ‡Miller, George. Brentry, near Bristol.
1895. ‡Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John, B.D. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1895. §Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1897. §Miller, Willet G., Professor of Geology in Queen's University, Kingston, Ontario, Canada.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. §Mills, Mansfeldt H., M.Inst.C.E., F.G.S. Sherwood Hall, Mansfield.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *Milne, John, F.R.S., F.G.S. Shide Hill House, Shide, Isle of Wight.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, N.W.
1880. ‡Minchin, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, W.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1879. ‡Mivart, St. George, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. 77 Inverness-terrace, W.
1895. *Moat, William, M.A. Johnson, Eccleshall, Staffordshire.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *Mond, Ludwig, Ph.D., F.R.S., F.C.S. 20 Avenue-road, Regent's Park, N.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1896. ‡Moore, A. W., M.A. Woodbourne House, Douglas, Isle of Man.

Year of Election.

1884. ‡Moore, George Frederick. 49 Hardman-street, Liverpool.
1894. §Moore, Harold E. 41 Bedford-row, W.C.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.
*Moore, John Carrick, M.A., F.R.S., F.G.S. 113 Eaton-square, S.W.; and Corswall, Wigtonshire.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
1857. *Moore, Rev. William Prior. Carrickmore, Galway, Ireland.
1896. *Mordey, W. M. Princes-mansions, Victoria-street, S.W.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡Morgan, Alfred. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895. §Morgan, C. Lloyd, F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1891. ‡Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1896. §Morgan, George. 61 Hope-street, Liverpool.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1882. §Morgan, Thomas, J.P. Cross House, Southampton.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1893. ‡Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, N.W.
1889. ‡Morley, The Right Hon. John, M.A., LL.D., M.P., F.R.S. 95 Elm Park-gardens, S.W.
1896. §§Morrell, R. S. Caius College, Cambridge.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn, R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡Morris, Daniel, C.M.G., M.A., D.Sc., F.L.S. 12 Cumberland-road, Kew.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 4 The Elms, Liverpool.
1896. *Morris, J. T. 13 Somers-place, W.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1874. ‡Morrison, G. J., M.Inst.C.E. Shanghai, China.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §Morton, George H., F.G.S. 209 Edge-lane, Liverpool.
1858. *Morton, Henry Joseph. 2 Westbourne-villas, Scarborough.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hockliffe Grange, Leighton Buzzard.
1896. *Morton, William B., Professor of Natural Philosophy in Queen's College, Belfast.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1878. *Moss, John Francis, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, Richard Jackson, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. 5 Chiswick-place, Eastbourne.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.

Year of Election.

1873. ‡Mossman, William. Ovenden, Halifax.
1892. *Mostyn, S. G., B.A. 49 Grosvenor-road, Canonbury, N.
1869. §MOTT, ALBERT J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1866.§§MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.
1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.
1878. *MOULTON, J. FLETCHER, M.A., Q.C., F.R.S. 57 Onslow-square, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. The Wigwam, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Cheltenham.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1894. ‡Mugliston, Rev. J., M.A. Newick House, Cheltenham.
1876. *Muir, Sir John, Bart. Demster House, Perthshire.
1874. ‡MUIR, M. M. PATTISON, M.A. Caius College, Cambridge
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. 61 Warrender Park-road, Edinburgh.
1883. ‡MULHALL, MICHAEL G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1891. ‡MÜLLER, The Right Hon. F. MAX, M.A., Professor of Comparative Philology in the University of Oxford. 7 Norham-gardens, Oxford.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
1897. §Mullins, W. E. Preshute House, Marlborough, Wilts.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, E.C.
1876. ‡Munro, Donald, M.D., F.C.S. The University, Glasgow.
1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, JOHN, LL.D., Ph.D., F.R.S., F.R.S.E. 'Challenger' Expedition Office, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1874. §Musgrave, Sir James, Bart., J.P. Drumglass House, Belfast.
1897. §Musgrave, James, M.D. 511 Bloor-street West, Toronto, Canada.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.

Year of Election.

1891. ‡Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *Myres, John L., M.A., F.S.A. Christ Church, Oxford.

1886. §§Nagel, D. H., M.A. Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 34 Queen-street, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡Nares, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 1 Beaufort-villas, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D. Troy, New York, U S.A.
1896. §§Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. Dalton Hall, Victoria Park, Manchester.
1887. ‡Neill, Joseph S. Claremont, Broughton Park, Manchester.
1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1897. §Nesbitt, Beattie S. A., M.D. 71 Grosvenor-street, Toronto, Canada.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡Neville, F. H., M.A., F.R.S. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1889. §§Newstead, A. H. L., B.A. Roseacre, Epping.
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. ‡Newton, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1883. ‡Nias, Miss Isabel. 56 Montagu-square, W.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡Nicholson, Sir Charles, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1867. ‡Nicholson, Henry Alleyne, M.D., D.Sc., F.R.S., F.L.S., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.
1884. ‡Nicholson, Joseph S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.
1896. §§Nisbet, J. Tawse. 175 Lodge-lane, Liverpool.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.
1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1884. ‡Nixon, T. Alcock. 33 Harcourt-street, Dublin.
1863. *Noble, Sir Andrew, K.C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.

Year of Election.

1879. ‡Noble, T. S. Lendal, York.
1886. ‡Nock, J. B. Mayfield, Penns, near Birmingham.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. Houghton-le-Spring, R.S.O., Co. Durham.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, R.S.O., Shropshire.
1881. ‡North, William, B.A. 84 Micklegate, York.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. 98 Anglesea-road, Ipswich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1896. §Nugent, the Right Rev. Monsignor. 18 Adelaide-terrace, Waterloo, Liverpool.
1887. ‡Nursey, Perry Fairfax. 2 Trafalgar-buildings, Northumberland-avenue, London, W.C.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1894. §§Ogden, James. Kilner Deyne, Rochdale.
1896. §Ogden, Thomas. 4 Prince's-avenue, Liverpool.
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. Heriot Watt College, Edinburgh.
1893. ‡Ogilvie, Miss Maria M., D.Sc. Gordon's College, Aberdeen.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., C.M.G. Royal Colonial Institute, Northumberland-avenue, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡Oldham, Charles. Romiley, Cheshire.
1896. §§Oldham, G. S. Town Hall, Birkenhead.
1892. ‡Oldham, H. Yule, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1893. ‡Oldham, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, E.C.
1892. ‡Oliphant, James. 50 Palmerston-place, Edinburgh.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.

Year of
Election.

1887. ‡Oliver, F. W., D.Sc., F.L.S., Professor of Botany in University College, London. The Tower House, Tite-street, Chelsea, S.W.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1860. *OMMANNEY, Admiral Sir ERASMUS, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, W.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1872. ‡Onslow, D. Robert. New University Club, St. James's, S.W.
1883. ‡*Oppert, Gustav, Professor of Sanskrit. Madras.*
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. ‡Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. ‡Ord, Miss Sarah. 2 Pembroke-vale, Clifton, Bristol.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Lieut.-Colonel R. T., R.E. Care of G. H. Orpen, Esq., Erpingham, Bedford Park, Chiswick.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1897. §Osborne, James K. 40, St. Joseph-street, Toronto, Canada.
1887. §O'Shea, L. T., B.Sc. University College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1897. §Osler, E. B., M.P., Rosedale, Toronto, Canada.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡Osler, William, M.D. Johns Hopkins University, Baltimore, U.S.A.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. §§Oulton, W. Hillside, Gateacre, Liverpool.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester.
1888. *Owen, Thomas, M.P. Henley-grove, Westbury-on-Trym, Bristol.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1894. ‡Paget, Octavius. 158 Fenchurch-street, E.C.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1896. §§Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1883. §Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.

Year of
Election.

1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1884. ‡Panton, Professor J. Hoyes, M.A., Ontario Agricultural College, Guelph, Ontario, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1879. ‡Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, N.E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1865. *Parsons, Charles Thomas. Mountlands, Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. Elvaston Hall, Newcastle-upon-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡Paterson, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1897. §Paterson, John A. 23 Walmer-road, Toronto, Canada.
1896.§§Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1884. *Paton, David. Johnstone, Scotland.
1897. §Paton, D. Noël, M.D. 33 George-square, Edinburgh.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. Care of the Sheddon Co., Montreal, Canada.
1871. *Patterson, A. Henry. 16 Ashburn-place, S.W.
1876. ‡Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1867. ‡Pattison, Samuel Rowles. 11 Queen Victoria-street, E.C.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, F. WILLIAM, M.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Stisted Hall, near Braintree, Essex.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. 1 Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. 1 Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, W.C.
1881. *PEARCE, HORACE, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.

Year of Election.

1888. §Pearce, Rev. R. J., D.C.L. The Vicarage, Bedlington, R.S.O., Northumberland.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, Richard. 57 Bootham, York.
1883. *Pearson, Thomas H. Redclyffe, Newton-le-Willows, Lancashire.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
*Peckover, Alexander, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron Park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡PEEK, CUTHBERT E., M.A., F.S.A. 22 Belgrave-square, S.W.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, S.W.
1861. *Peile, George. Greenwood, Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, W.C.
1887. §§PENDLEBURY WILLIAM H., M.A., F.C.S. 6 Gladstone-terrace, Priory Hill, Dover.
1894. §Pengelly, Miss. Lamorna, Torquay.
1894. §Pengelly, Miss Hester. Lamorna, Torquay.
1897. §Penhallow, Professor D. P., M.A. McGill University, Montreal, Canada.
1896. §Pennant, P. P. Nantlys, St. Asaph.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 16 Ellison-place, Newcastle-upon-Tyne.
1895. §Percival, John, M.A., Professor of Botany in the South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Cambridge Cottage, Kingswood, Reigate.
1894. ‡Perkin, A. G., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Woodhouse Cliff, Leeds.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡PERKIN, WILLIAM HENRY, jun., Ph.D., F.R.S., F.C.S., Professor of Organic Chemistry in Owens College, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, N.W.
1886. ‡Perrin, Mrs. 31 St. John's Wood Park, N.W.
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.

Year of Election.

1897. §Peters, Dr. George A. 171 College-street, Toronto, Canada.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1895. §PETRIE, W. M. FLINDERS, D.C.L., Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Brighton.
1886. ‡Phelps, Major-General A. 23 Augustus-road, Edgbaston, Birmingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, S.W.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1896. §Philip, George, jun. 14 Holly-road, Fairfield, Liverpool.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, George-lane, Woodford, Essex.
1863. ‡Philipson, Dr. 7 Eldon-square, Newcastle-upon-Tyne.
1889. ‡Philipson, John. 9 Victoria-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F.C.S. 183 Moss-lane East, Manchester.
1892. §Phillips, J. H. Poole, Dorset.
1890. §Phillips, R. W., M.A., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1885. *PICKERING, SPENCER U., M.A., F.R.S. 48 Bryanston-square, W.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1896.§ §Picton, W. H. College-avenue, Crosby, Liverpool.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, N.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, W.
1873. ‡Pike, W. H., M.A., Ph.D., Professor of Chemistry in the University of Toronto, Canada.
1896. *Pilkington, A. C. The Hazels, Prescot, Lancashire.
1896. *Pilling, William. Rosario, Skeene-road, West Worthing.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1884. ‡*Pirz, Anthony. Long Island, New York, U.S.A.*
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, S.E.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, E.C.
1893. *Pitt, Walter, M.Inst.C.E. South Stoke House, near Bath.
1868. ‡PITT-RIVERS, Lieut.-General A. H. L., D.C.L., F.R.S., F.G.S., F.S.A. 4 Grosvenor-gardens, S.W.

Year of Election.

1842. PLAYFAIR, The Right Hon. Lord, G.C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. 68 Onslow-gardens, South Kensington, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel Sir R. L., K.C.M.G., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 38 Grosvenor-street, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, S.W.
1893. ‡Plowright, Henry J. Brampton Foundries, Chesterfield.
1897. §Plummer, J. H. Bank of Commerce, Toronto, Canada.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1846. ‡POLE, WILLIAM, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, S.W.
1896. §Pollard, James. High Down, Hitchin, Herts.
1896. *Pollex, Albert. Dale End, Cavendish Park, Rockferry.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1892. §Popplewell, W. C., M.Sc., Assoc. M. Inst. C.E. Yorkshire College, Leeds.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Portland-terrace, Newcastle-upon-Tyne.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S., Professor of Zoology in the University of Oxford. Wykeham House, Banbury Road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Waunarlwydd House, near Swansea.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, St. Ann-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1883. ‡POYNTING, J. H., D.Sc., F.R.S., Professor of Physics in the Mason College, Birmingham.
1884. ‡Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. 27 Norham-road, Oxford.
1891. ‡Pratt, Bickerton. Brynderwen, Maindee, Newport, Monmouthshire.
1869. *PREECE, WILLIAM HENRY, C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1888. *Preece, W. Llewellyn. Telegraph Department, Midland Railway, Derby.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1894. §Prentice, Manning, F.C.S. Woodfield, Stowmarket.
1892. §Prentice, Thomas. Willow Park, Greenock.

Year of Election.

1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1894. ‡Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. 9 St. James's-terrace, Nottingham.
1893. §PRESTON, Professor THOMAS. Bardowie, Orwell Park, Dublin.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., D.D., F.R.S., F.R.A.S., Master of Pembroke College, Oxford.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1897. *Price, W. A., M.A. Teign House, Westcombe Park Road, S.E.
1897. §Primrose, Dr. Alexander. 196, Simcoe-street, Toronto, Canada.
1892. ‡Prince, Professor Edward E., B.A. Ottawa, Canada.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. St. Giles, Norwich.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1888. ‡Probyn, Leslie C. Onslow-square, S.W.
1881. §Procter, John William. Ashcroft, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Slade-road, Ilfracombe.
1872. *Pryor, M. Robert. Weston, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Ochil, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Castlewood, Park-road, Moseley, Birmingham.
1887. §PUMPHREY, WILLIAM. 2 Oakland-road, Redland, Bristol.
1885. §§PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. ‡Purrott, Charles. West End, near Southampton.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. Willesley, Park Hill Rise, Croydon.
1883. §Pye-Smith, Mrs. Willesley, Park Hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1896. §§Quaill, Edward. 3 Palm-grove, Claughton.
1893. ‡Quick, James. University College, Bristol.
1894. ‡Quick, Professor Walter J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, S.W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.

Year of Election.

1896. §Radcliffe, Herbert. Balderstone Hall, Rochdale.
1877. ‡Radford, George D. Mannamead, Plymouth.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1888. ‡Radway, C. W. 9 Bath-street, Bath.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, W.
1896. *Ramage, Hugh. 10 Bridle-road, Crewe.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.A.S., M.R.I.A., Radcliffe Observatory, Oxford.
1863. ‡RAMSAY, ALEXANDER. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1885. ‡Ramsay, Major. Straloch, N.B.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1876. *RAMSAY, WILLIAM, Ph.D., F.R.S., Professor of Chemistry in University College, London. 12 Arundel-gardens, W.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, W.
1835. *Rance, Henry. 6 Ormond-terrace, Regent's Park, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1893. ‡Ransom, W. B., M.D. The Pavement, Nottingham.
1863. ‡RANSOM, WILLIAM HENRY, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S., Professor of Public Health in Owens College, Manchester. Sunninghurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1892. §Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. §Rathbone, R. R. Glan y Menai, Anglesey.
1895. ‡RATHBONE, W., LL.D. Green Bank, Liverpool.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. 2 York Mansions, Battersea Park, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1875. §RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, S.W.
1886. ‡Rawson, W. Stepney, M.A. 68 Cornwall-gardens, Queen's-gate, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution. Terling Place, Witham, Essex.
1895. §§Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree. Mayfield House, Ashbourne.
1896. §Read, Charles H., F.S.A. British Museum, W.C.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.

Year of Election.

1892. ‡Redgrave, Gilbert R., Assoc.M.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
1863. ‡Redmayne, Giles. 20 New Bond-street, W.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. 4 Bishopsgate-street Within, E.C.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡Reed, Sir Edward James, K.C.B., F.R.S. 75 Harrington-gardens, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill, Carlisle.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. 15 Merridale-lane, Wolverhampton.
1891. §Rees, I. Treharne, M Inst.C.E. Highfield, Penarth.
1891. ‡Rees, Samuel. West Wharf, Cardiff.
1891. ‡Rees, William. 25 Park-place, Cardiff.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1897. §Reeve, Richard A. 22 Shuter-street, Toronto, Canada.
1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *Reid, Clement, F.L.S., F.G.S. 28 Jermyn-street, S.W.
1892. ‡Reid, E. Waymouth, B.A., Professor of Physiology in University College, Dundee.
1889. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1897. §Reid, T. W., M.D. St. George's House, Canterbury.
1892.§§Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1893. ‡Reinach, Baron Albert von. Frankfort s. M., Prussia.
1875. §Reinold, A. W., M.A., F.R.S., Professor of Physics in the Royal Naval College, Greenwich, S.E.
1863. ‡Renals, E. 'Nottingham Express' Office, Nottingham.
1894.§§Rendall, G. H., M.A., Principal of University College, Liverpool.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Bank House, Birkdale, Southport.
1871. ‡Reynolds, James Emerson, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *Reynolds, Osborne, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 23 Lady Barn-road, Fallowfield, Manchester.
1858. §Reynolds, Richard, F.C.S. Cliff Lodge, Hyde Park, Leeds.
1896.§§Reynolds, Richard S. 73 Smithdown-lane, Liverpool.
1896. §Rhodes, Albert. Fieldhurst, Liversidge, Yorkshire.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1858. *Rhodes, John. Potternewton House, Chapel Allerton, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. ‡Rhodes, John George. Warwick House, 46 St. George's-road, S.W.
1890. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Rua Muro, 14, Modena, Italy.

Year of
Election.

1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D. University College, Bristol.
1869. *Richardson, Charles. 6 The Avenue, Bedford Park, Chiswick.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. 27 New Walk, Leicester.
1889. ‡Richardson, Hugh. Sedbergh School, Sedbergh R.S.O., Yorkshire.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡Richardson, W. B. Elm Bank, York.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Heathwood, Leighton Buzzard.
1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-mansions, S.W.
1894.§§RIDLEY, E. P. 6 Paget-road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, N.W.
1889. ‡Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1881. *Rigg, Arthur. 152 Blomfield-terrace, W.
1883. *RIGG, EDWARD, M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, S.W.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1869. *Rivington, John. Babbicombe, near Torquay.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, London, N.W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1894. *Roberts, Miss Janora. 5 York-road, Birkdale, Southport.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, E.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 31 North-road, Cowley Hill, St. Helens.
1883. ‡ROBERTS, Sir WILLIAM, M.D., F.R.S. 8 Manchester-square, W.
1868. *ROBERTS-AUSTEN, W. CHANDLER, C.B., F.R.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. (GENERAL SECRETARY.) Royal Mint, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1883. †Robertson, George H. Plas Newydd, Llangollen.

Year of Election.

1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1897. §Robertson, Sir George S., K.C.S.I. Care of Messrs. Wm. Watson & Co., 7 Waterloo-place, S.W.
1897. §Robertson, Professor J. W. Department of Agriculture, Ottawa, Canada.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. *Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, N.W.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1897. §Robinson, Haynes. St. Giles's Plain, Norwich.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, S.W.
1888. ‡Robinson, John. 8 Vicarage-terrace, Kendal.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891. ‡Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1890. ‡Rochester, The Right Rev. the Lord Bishop of. Kennington Park, S.E.
1896. §§Rock, W. H. 75 Botanic-road, Liverpool.
1896. §§Rodger, Alexander M. The Museum, Tay Street, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
1898. §Rogers, Bertram, M.D. (Local Secretary.) 11 York Place, Clifton, Bristol.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1884. *Rogers, Walter M. Lamowa, Falmouth.
1889. ‡Rogerson, John. Croxdale Hall, Durham
1897. §Rogerson, John. Barrie, Ontario, Canada.
1876. ‡Rollit, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1892. *Romanes, John. 3 Oswald-road, Edinburgh.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1894. *Rooper, T. Godolphin. The Elms, High Harrogate.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1881. *Roper, W. O. Bank-buildings, Lancaster.
1855. *Roscoe, Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., F.R.S. 10 Bramham-gardens, S.W.
1892. ‡Rose, Hugh. Kilravock Lodge, Blackford-avenue, Edinburgh.
1883. *Rose, J. Holland, M.A. 11 Endlesham-road, Balham, S.W.
1894. *Rose, T. K., D.Sc. 9 Royal Mint, E.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1887. ‡Ross, Edward. Marple, Cheshire.

Year of Election.

1880. ‡Ross, Captain G. E. A., F.G.S. 8 Collingham-gardens, Cromwell-road, S.W.
1897. §Ross, Hon. Alexander M. 3 Walmer-road, Toronto, Canada.
1897. §Ross, Hon. G.W., Minister of Education for the Province of Ontario. Toronto, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. §Roth, H. Ling. 32 Prescott-street, Halifax, Yorkshire.
1893. ‡Rothera, G. B. Sherwood Rise, Nottingham.
1865. *Rothera, George Bell, F.L.S. Orston House, Sherwood Rise, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 54 Westbourne-villas, West Brighton.
1861. ‡ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1887. ‡*Rowe, Rev. Alfred W., M.A. Felstead, Essex.*
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.
1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *ROWNTREE, JOHN S. Mount Villas, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1888. ‡*Roy, Parbati Churn, B.A. Calcutta, Bengal, India.*
1875. *RÜCKER, A. W., M.A., D.Sc., Sec.R.S., Professor of Physics in the Royal College of Science, London. (GENERAL TREASURER.) 19 Gledhow-gardens, South Kensington, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonards-on-Sea.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Union-court Chambers, Old Broad-street, E.C.
1896. §§Rundell, T. W. 25 Castle-street, Liverpool.
1887. §Ruscoe, John. Ferndale, Gee Cross, near Manchester.
1847. ‡RUSKIN, JOHN, M.A., D.C.L., F.G.S. Brantwood, Coniston, Ambleside.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, S.E.
Russell, John. 39 Mountjoy-square, Dublin.
1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 16 Bardwell-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, W.
1876. ‡Russell, Robert, F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S. 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1897. §Rutherford, A. Toronto, Canada.
1891. §Rutherford, George. Dulwich House, Pencisely-road, Cardiff.
1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Edinburgh.

Year of Election.

1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
1879. ‡Ruxton, Vice-Admiral Fitzherbert, R.N. 41 Cromwell-gardens, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, E.C.
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1897. §Ryerson, G. S., M.D. Toronto, Canada.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, E.C.
1885. ‡Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1886. §St. Clair, George, F.G.S. 225 Castle-road, Cardiff.
1893. ‡Salisbury, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S. 20 Arlington Street, S.W.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Provost of Trinity College, Dublin.
1883. ‡Salmond, Robert G. Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1872. ‡Salvin, Osbert, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1894. ‡Samuelson, The Right Hon. Sir Bernhard, Bart., F.R.S., M.Inst.C.E. 56 Prince's-gate, S.W.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, S.W.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
1872. §Sanderson, J. S. Burdon, M.A., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Regius Professor of Medicine in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. §Sang, William D. 28 Whyte's Causeway, Kirkcaldy, Fife.
1886. §Sankey, Percy E. Down Lodge, Fairlight, Hastings.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1896. §§Sargant, W. L. Quarry Hill, Reigate.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83a Edmund-street, Birmingham.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡Saunders, Howard, F.L.S., F.Z.S. 7 Radnor-place, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡Saunders, Trelawney W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡Saunders, William. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.

Year of Election.

1887. §Savage, Rev. Canon E. B., M.A., F.S.A. St. Thomas' Vicarage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1872. *Sawyer, George David. 55 Buckingham-place, Brighton.
1887. §Sayce, Rev. A. H., M.A., D.D., Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *Schäfer, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. (General Secretary.) Croxley Green, Rickmansworth.
1888. *Scharff, Robert F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. ‡Schloss, David F. 1 Knaresborough-place, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. Eden-terrace, Harriet-street, Stretford, Manchester.
Schunck, Edward, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
1847. *Sclater, Philip Lutley, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, W.
1883. *Sclater, W. Lutley, M.A., F.Z.S. South African Museum, Cape Town.
1867. ‡Scott, Alexander. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., D.Sc. University Chemical Laboratory, Cambridge.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. §Scott, Miss Charlotte Angas, D.Sc. Lancashire College, Whalley Range, Manchester.
1889. *Scott, D. H., M.A., Ph.D., F.R.S., F.L.S. The Old Palace, Richmond, Surrey.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1897. §Scott, James. 173 Jameson-avenue, Toronto, Canada.
1857. *Scott, Robert H., M.A., F.R.S., F.R.Met.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1895. §Scott-Elliott, G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. 2 Langland-gardens, Finchley-road, N.W.
1890. §Searle, G. F. C., M.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880 ‡Sedgwick, Adam, M.A., F.R.S. Trinity College, Cambridge.
1861. *Seeley, Harry Govier, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 25 Palace Gardens-terrace, Kensington, W.

Year of Election.

1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1893. ‡SELBY-BIGGE, L. A., M.A. University College, Oxford.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, E.C.
1897. §Selous, F. C., F.R.G.S. Alpine Lodge, Worplesden, Surrey.
1884. ‡SELWYN, A. R. C., C.M.G., F.R.S. Ottawa, Canada.
1885. ‡Semple, Dr. A. United Service Club, Edinburgh.
1887. §Semple, James C., F.R.G.S., M.R.I.A. 2 Marine-terrace, Kingstown, Co. Dublin.
1892. ‡*Semple, William. Gordon's College, Aberdeen.*
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1858. *Senior, George. Ashgate-road, Chesterfield.
1888. *Sennett, Alfred R., A.M.Inst.C.E. The Chalet, Portinscale-road, Putney, S.W.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. §§Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1895. *Seton-Karr, H. W. Atherton Grange, Wimbledon, Surrey.
1892. §Seward, A. C., M.A., F.G.S. Westfield, Huntingdon-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 30 St. Charles-square, Ladbroke Grove-road, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1896. §§Sharp, Mrs. E. 65 Sankey-street, Warrington.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
1883. ‡Sharples, Charles H. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. §§Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1887. *Shaw, James B. 7 The Beeches, Didsbury, Manchester.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Halberton, near Tiverton, Devon.
1887. §§Shaw, Saville, F.C.S. College of Science, Newcastle-upon-Tyne.
1883. *SHAW, W. N., M.A., F.R.S. Emmanuel House, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1884. ‡*Sheldon, Professor J. P. Downton College, near Salisbury.*
1878. ‡Shelford, William, M.Inst.C.E. 35A Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1890. ‡Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.

Year of Election.

1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1896. §SHERRINGTON, C. S., M.D., F.R.S., Professor of Physiology in University College, Liverpool. 16 Grove-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, S.W.
1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey, S.W.
1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, J. N., M.Inst.C.E. 47 Victoria-street, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, W.C.
1897. §Shore, Dr. Lewis E. St. John's College, Cambridge.
1875. ‡SHORE, THOMAS W., F.G.S. Hartley Institution, Southampton.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital, E.C.
1897. §Shortt, Professor Adam, M.A. Queen's University, Kingston, Ontario, Canada.
1889. ‡Sibley, Walter K., B.A., M.B. 7 Upper Brook-street, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson, M.P. Erlesdene, Bowdon, Cheshire.
1885. *SIDGWICK, HENRY, M.A., Litt.D., D.C.L., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 7 Airlie-gardens, Campden Hill, W.
1878. ‡SIGERSON, Professor GEORGE, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1862. ‡Simms, James. 138 Fleet-street, E.C.
1874. ‡Simms, William. Upper Queen-street, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, W.
1887. *Simon, Henry. Lawnhurst, Didsbury, near Manchester.
1893. ‡Simpson, A. H., F.R.Met.Soc. Attenborough, Nottinghamshire.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S. 9 Barton-street, West Kensington, W.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
1896. *Simpson, W., F.G.S. The Gables, Halifax.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P. Rivelyn, Prince's Park, Liverpool.
1897. §Sinnott, James. Bank of England-chambers, 12 Broad-street, Bristol.

Year of Election.

1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. ‡Sisley, Richard, M.D. 11 York-street, Portman-square, W.
1879. ‡Skertchly, Sydney B. J. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1892. ‡Skinner, William. 35 George-square, Edinburgh.
1888. §Skrine, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. 13 Hyde Park-gate, S.W.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S. Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, Evan W., M.A., B.Sc., F.G.S. County Council Offices, Newport, Monmouthshire.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1885. §§Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. ‡Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡Smith, Adam Gillies, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. The University, Chicago, Illinois, U.S.A.
1897. §Smith, Andrew. Principal of the Veterinary College, Toronto, Canada.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡Smith, David, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897. §Smith, Sir Frank. Toronto, Canada.
1892. ‡*Smith, Rev. Frederick.* 16 *Grafton-street, Glasgow.*
1885. ‡Smith, Rev. G. A., M.A. 21 Sardinia-terrace, Glasgow.
1897. §Smith, G. Elliot, M.D. St. John's College, Cambridge.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 49 Beaumont-square, E.

Year of Election.

1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1883. ‡Smith, M. Holroyd. Royal Insurance Buildings, Crossley-street, Halifax.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡SMITH, ROBERT H., M.Inst.C.E., Professor of Engineering in the Mason Science College, Birmingham.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1894. §Smith, T. Walrond. 32 Victoria Street, Westminster, S.W.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, W.C.
1896. *Smith, Rev. W. Hodson. 31 Esplanade Gardens, Scarborough.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton Downs, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡SMITHELLS, ARTHUR, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1892. §§Smithson, G. E. T. Tyneside Geographical Society, Barras Bridge, Newcastle-upon-Tyne.
1882. ‡Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S. Clova, Ripon.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1857. *SMYTH, JOHN, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.
1897. §Snelgrove, C. F., M.D. Meaford, Ontario, Canada.
1888. ‡Snell, Albion T. Brightside, Salusbury-road, Brondesbury, N.W.
1878. §Snell, H. Saxon. 22 Southampton-buildings, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.
1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Oxford.
1892. *Somervail, Alexander. Torquay.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1892. ‡Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.
1888. ‡Sorley, Professor W. R. University College, Cardiff.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1887. §Sowerbutts, Eli, F.R.G.S. 44 Brown-street, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.

Year of Election.

1863. *Spark, H. King, F.G.S. Startforth House, Barnard Castle.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newburn, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, N.
1894. ‡Spiers, A. H. Newton College, South Devon.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 41 Grosvenor-place, S.W.
1854. *Sprague, Thomas Bond, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
1897. §Squire, W. Stevens, M.D. Charendon House, St. John's Wood Park, N.W.
1888. *Stacy, J. Sargeant. 15 Wolseley-road, Crouch End, N.
1897. §Stafford, Joseph. Morrisburg, Ontario, Canada.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1865. ‡Stanford, Edward C. C., F.C.S. Glenwood, Dalmuir, N.B.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
1894. *Stansfield, Alfred. Royal Mint, E.
1893. ‡Staples, Sir Nathaniel, Bart. Lisson, Cookstown, Ireland.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1876. ‡Starling, John Henry, F.C.S. 3 Victoria-road, Old Charlton, Kent.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1881. ‡Stead, W. H. Orchard-place, Blackwall, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. *Stebbing, Rev. Thomas R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 169 Gloucester-terrace, W.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1887. ‡Steinthal, Rev. S. Alfred. 81 Nelson-street, Manchester.
1887. ‡Stelfox, John L. 6 Hilton-street, Oldham, Manchester.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Lowville, Lewis County, New York, U.S.A.
1879. *Stephenson, Sir Henry, J.P. The Glen, Sheffield.
1880. *Stevens, J. Edward, LL.B. Le Mayals, near Swansea.

Year of Election.

1886. ‡Stevens, Marshall. Highfield House, Urmston, near Manchester.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C. Westoe, South Shields.
1890. *Steward, Rev. Charles J., F.R.M.S. Somerleyton Rectory, Lowestoft.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1887. **Stewart, A. H. St. Thomas's Hospital, London, S.E.*
1864. ‡STEWART, CHARLES, M.A., F.R.S., F.L.S., Hunterian Professor and Conservator of the Museum, Royal College of Surgeons, Lincoln's Inn Fields, W.C.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. Bandora, Bridge of Allan, N.B.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1892. ‡Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. ‡Stone, E. D., F.C.S. 19 Lever-street, Piccadilly, Manchester.
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
1886. ‡Stone, Sir J. Benjamin, M.P. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1876. ‡Stone, Octavius C., F.R.G.S. 49 Bolsover-street, Regent's Park, N.W.
1883. ‡Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, W.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1895. *Stoney, Miss Edith A. 8 Upper Hornsey Rise, N.
1878. *Stoney, G. Gerald. 7 Roxburgh-place, Heaton, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, N.
1876. §§Stopes, Henry. Mansion House, Swanscombe, Greenhithe, Kent.
1883. ‡Stopes, Mrs. Mansion House, Swanscombe, Greenhithe, Kent.
1887. *Storey, H. L. Yealand Conyers, Carnforth.
1884. §Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. 3 Park Lane, Bath.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General SIR RICHARD, R.E., G.C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.

Year of Election.

1889. ‡Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, S.W.
1889. §§Streatfeild, H. S., F.G.S. Ryhope, near Sunderland
1879. ‡Strickland, Sir Charles W., Bart., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1887. *Stroud, Professor H., M.A., D.Sc. College of Science, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *STRUTHERS, JOHN, M.D., LL.D., Emeritus Professor of Anatomy in the University of Aberdeen. 24 Buckingham-terrace, Edinburgh.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. St. Matthew, Bayswater, 5 Prince's-square, W.
1892. ‡Stuart, Morton Gray, M.A. Ettrickbank, Selkirk.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893. ‡Stubbs, Arthur G. Sherwood Rise, Nottingham.
1896. §§Stubbs, Miss. Torrisholme, Aigburth-drive, Sefton Park, Liverpool.
1888. *Stubbs, Rev. E. Thackeray, M.A. Grove Lea, Lansdowne-grove, Bath.
1885. ‡Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1897. §Stupart, R. F. The Observatory, Toronto, Canada.
1879. *Styring, Robert. 64 Crescent-road, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. University College, Nottingham.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. ‡Sutherland, James B. 10 Windsor-street, Edinburgh.
1884 ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1881. §SWAN, JOSEPH WILSON, M.A., F.R.S. 58 Holland-park, W.
1897. §Swanston, William, F.G.S. Queen-street, Belfast.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §§SWINBURNE, JAMES. 4 Hatherley-road, Kew Gardens.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1890. §SWINHOE, Colonel C., F.L.S. Avenue House, Oxford.
1891. ‡Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1889. §Sworn, Sidney A., B.A., F.C.S. The Municipal Technical School, Gravesend.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1895. §§Sykes, E. R. 3 Gray's Inn-place, W.C.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, Elmbourne-road, Tooting Common, S.W.

Year of Election.

1896. §Sykes, Mark L. 19 Manor-street, Ardwick, Manchester.
1887. *Sykes, T. H. Cringle House, Cheadle, Cheshire.
1893. ‡Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡Symington, Johnson, M.D. Queen's College, Belfast.
1881. *Symington, Thomas. Wardie House, Edinburgh.
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, N.W.
1855. *SYMONS, WILLIAM. Dragon House, Bilbrook, near Taunton.
1886. §Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.

1896. §Tabor, J. M. 20 Petherton-road, Canonbury, N.
1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
1877. *TAIT, LAWSON, F.R.C.S. 7 The Crescent, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡Tait, P. M., F.S.S. 6 Rossetti-mansions, Cheyne-walk, S.W.
1894. ‡Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1893. ‡Talbot, Herbert, M.I.E.E. 19 Addison-villas, Addison-street, Nottingham.
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1891. ‡Tanner, Colonel H. C. B., F.R.G.S. Fièsole, Bathwick Hill, Bath.
1890. ‡TANNER, H. W. LLOYD, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.
1897. §Tanner, Professor J. H. Ithaca, New York, U.S.A.
1892. *Tansley, Arthur G. 167 Adelaide-road, N.W.
1883. *Tapscott, R. Lethbridge, Assoc.M.Inst.C.E., F.G.S., F.R.A.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. 190 Old Christchurch-road, Bournemouth.
1857. *Tate, Alexander. Rantalard, Whitehouse, Belfast.
1893. ‡Tate, George, Ph.D. College of Chemistry, Duke-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt. 13 Queen's-terrace, St. John's Wood, N.W.
1881. *Taylor, H. A. 25 Collingham-road, South Kensington, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1861. *Taylor, John, M.Inst.C.E., F.G.S. The Old Palace, Richmond, Surrey.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1895. ‡Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.

Year of Election.

1893. ‡Taylor, W. F. Bhootan, Whitehorse-road, Croydon, Surrey.
1894. *Taylor, W. W. 10 King-street, Oxford.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, S.W.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡Temple, The Right Hon. Sir Richard, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.G.S. Athenæum Club, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894. §Terras, J. A., B.Sc. Royal Botanic Gardens, Edinburgh.
1882. §§Terrill, William. 42 St. George's-terrace, Swansea.
1881. ‡Terry, Sir Joseph. Hawthorn Villa, York.
1896. *Terry, Rev. T. R. The Rectory, East Ilsley, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, W.C.
1885. ‡Thin, Dr. George, 22 Queen Anne-street, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡Thiselton-Dyer, W. T., C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. Royal Gardens, Kew.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Llwynmadoc, Garth, R.S.O.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. §Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1884. ‡Thomas, F. Wolferstan. Molson's Bank, Montreal, Canada.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §§Thomas, J. Blount. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. 88 Breakspear's-road, Brockley, S.E.
1891. ‡*Thomas, John Tubb, L.R.C.P. Eastfields, Newport, Monmouthshire.*
1880. *Thomas, Joseph William, F.C.S. 2 Hampstead Hill-mansions, N.W.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. ‡Thomason, Yeoville. 9 Observatory-gardens, Kensington, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., Professor of Zoology in University College, Dundee. University College, Dundee.
1896. *Thompson, Edward P. Whitchurch, Salop.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.

Year of Election.

1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.

1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, W.

1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.

1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.

1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.

1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. 53 Croxteth-road, Liverpool.

1897. §Thompson, J. Barclay. 37 St. Giles's, Oxford.

1891. ‡Thompson, J. Tatham. 23 Charles-street, Cardiff.

1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.

1876. *Thompson, Richard. Dringcote, The Mount, York.

1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.

1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S., Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.

1883. *Thompson, T. H. Redlynet House, Green Walk, Bowdon, Cheshire.

1896. *THOMPSON, W. H., M.D., Professor of Physiology in Queen's College, Belfast.

1896. §Thompson, W. P. 6 Lord-street, Liverpool.

1867. ‡Thoms, William. Magdalen-yard-road, Dundee.

1894. ‡Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.

1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.

1868. §THOMSON, JAMES, F.G.S. 6 Stewart-street, Shawlands, Glasgow.

1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.

1891. ‡Thomson, John. 70A Grosvenor-street, W.

1896.§ §Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.

1890. §Thomson, J. Arthur, M.A., F.R.S.E., Lecturer on Zoology at the School of Medicine, Edinburgh. 11 Ramsay-garden, Edinburgh.

1883. ‡THOMSON, J. J., M.A., D.Sc., F.R.S., Professor of Experimental Physics in the University of Cambridge. 6 Scrope-terrace, Cambridge.

1871. *THOMSON, JOHN MILLAR, F.R.S., Sec.C.S., Professor of Chemistry in King's College, London. 85 Addison-road, W.

1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.

1880. §Thomson, William J. Ghyllbank, St. Helens.

1897. §Thorburn, James, M.D. Toronto, Canada.

1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.

1887. ‡Thornton, John. 3 Park-street, Bolton.

1867. ‡Thornton, Sir Thomas. Dundee.

1883. §Thorowgood, Samuel. Castle-square, Brighton.

1845. ‡Thorp, Dr. Disney. Lypiatt Lodge, Suffolk Lawn, Cheltenham.

1881. ‡Thorp, Fielden. Blossom-street, York.

1881. *Thorp, Josiah. Undercliffe, Holmfirth.

1864. *THORP, WILLIAM, B.Sc., F.C.S. 22 Sinclair-gardens, West Kensington, W.

1871. ‡THORPE, T. E., Ph.D., LL.D., F.R.S., F.R.S.E., Treas.C.S., Principal of the Government Laboratories, Clement's Inn-passage, W.C.

1883. §Threlfall, Henry Singleton, J.P. 12 London-street, Southport.

1896. §Thrift, William Edward. 80 Grosvenor-square, Rathmines, Dublin.

1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.

1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.

1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.

Year of Election.

1873. *Tiddeman, R. H., M.A., F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.

1874. ‡Tilden, William A., D.Sc., F.R.S., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London. 9 Ladbroke-gardens, W.

1873. ‡Tilghman, B. C. Philadelphia, U.S.A.

1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.

1883. ‡Tillyard, Mrs. Fordfield, Cambridge.

1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.

1896. §Timmis, Thomas Sutton. Cleveley, Allerton.

1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, S.E.

1891. ‡Todd, Richard Rees. Portuguese Consulate, Cardiff.

1897. §Todhunter, James. 85 Wellesley-street, Toronto, Canada.

1889. §Toll, John M. Carlton House, Kirkby, near Liverpool.

1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.

1896. §§Toms, Frederick. 1 Ambleside-avenue, Streatham, S.W.

1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.

1887. ‡Tonge, James, F.G.S. Woodbine House, West Houghton, Bolton.

1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.

1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.

1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, S.W.

1887. ‡Topham, F. 15 Great George-street, S.W.

1886. ‡*Topley, Mrs. W. 13 Havelock-road, Croydon.*

1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.

1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.

1884. ‡Torrance, John F. Folly Lake, Nova Scotia, Canada.

1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.

Towgood, Edward. St. Neots, Huntingdonshire.

1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.

1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.

1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.

1877. ‡Tozer, Henry. Ashburton.

1876. *Trail, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.

1883. ‡Traill, A., M.D., LL.D. Ballylough, Bushmills, Ireland.

1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.

1868. ‡Traquair, Ramsay H., M.D., LL.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.

1891. ‡Trayes, Valentine. Maindell Hall, Newport, Monmouthshire.

1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.

1868. ‡Trehane, John. Exe View Lawn, Exeter.

1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.

Trench, F. A. Newlands House, Clondalkin, Ireland.

1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.

1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.

1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.

1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.

1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.

1871. ‡Trimen, Roland, F.R.S., F.L.S., F.Z.S. 5 Lancaster-street, Lancaster Gate, W.

1860. §Tristram, Rev. Henry Baker, D.D., LL.D., F.R.S., Canon of Durham. The College, Durham.

Year of Election.

1884. *Trotter, Alexander Pelham, Government Electrician and Inspector. The Treasury, Cape Town.
1885. §TROTTER, COUTTS, F.G.S., F.R.G.S. 10 Randolph-crescent, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *Trouton, Frederick T., M.A., D.Sc., F.R.S. Trinity College, Dublin.
1896. §Truell, Henry Pomeroy, M.B., F.R.C.S.I. Clonmannon, Ashford, Co. Wicklow.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1887. ‡Tuke, W. C. 29 Princess-street, Manchester.
1883. ‡TUPPER, The Hon. Sir CHARLES, Bart., G.C.M.G., C.B. 17 Victoria-street, S.W.
1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1896 §§Turner, Alfred. Elmswood Hall, Aigburth, Liverpool.
1893. §Turner, Dawson, M.B. 37 George-square, Edinburgh.
1882. ‡Turner, G. S. Pitcombe, Winchester-road, Southampton.
1883. ‡Turner, Mrs. G. S. Pitcombe, Winchester-road, Southampton.
1894. *TURNER, H. H., M.A., B.Sc., F.R.S., Sec. R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1886. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C. Ravenhurst, Rowley Park, Stafford.
1863. *TURNER, Sir WILLIAM, M.B., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1893. ‡TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.
1890. *Turpin, G. S., M.A., D.Sc. School House, Swansea.
1883. ‡*Turrell, Miss S. S. High School, Redland-grove, Bristol.*
1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.
1886. *Twigg, G. H. 56 Claremont-road, Handsworth, Birmingham.
1888. §§Tyack, Llewellyn Newton. University College, Bristol.
1882. ‡Tyer, Edward. Horneck, 16 Fitzjohn's-avenue, Hampstead, N.W.
1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S., Professor of Anthropology, and Keeper of the University Museum, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1897. §Tyrrell, J. B., M.A., B.Sc. Ottawa, Canada.
1861. *Tysoe, John. Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 150 Holland-road, W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.

Year of Election.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1896. §§Vacher, Francis. 7 Shrewsbury-road, Birkenhead.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1886. ‡Vardy, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, N.
1865. *Varley, S. Alfred. 5 Gayton-road, Hampstead, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, W.
1895. §§Vaughan, D. T. Gwynne. Howry Hall, Llandrindod, Radnorshire.
1887. *Vaughan, His Eminence Cardinal. Carlisle-place, Westminster, S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §Veley, V. H., M.A., F.R.S., F.C.S. 22 Norham-road, Oxford.
1873. *Verney, Sir Edmund H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1883. ‡Vernon, H. H., M.D. York-road, Birkdale, Southport.
1896. *Vernon, Thomas T. 24 Waterloo-road, Waterloo, Liverpool.
1896. *Vernon, William. Tean Hurst, Tean, Stoke-upon-Trent.
1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Major R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. *Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1891. ‡Vivian, Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. ‡Wadsworth, G. H. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §Wager, Harold W. T. Bank View, Chapel Allerton, Leeds.
1896. §§Wailes, Miss Ellen. Woodmead, Groombridge, Sussex.
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡Wake, Charles Staniland. Welton, near Brough, East Yorkshire.
1892. ‡Walcot, John. 50 Northumberland-street, Edinburgh.
1884. ‡Waldstein, C., M.A., Ph.D. Slade Professor of Fine Art in the University of Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. ‡Walford, Edwin A., F.G.S. West Bar, Banbury.
1882. *Walkden, Samuel. Downside, Whitchurch, Tavistock.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1893. §Walker, Alfred O., F.L.S. Nant-y-Glyn, Colwyn Bay.
1890. ‡Walker, A. Tannett. Hunslet, Leeds.

Year of Election.

1897. *WALKER, B. E. Canadian Bank of Commerce, Toronto.
1885. ‡Walker, C. C., F.R.A.S. Lillieshall Old Hall, Newport, Shropshire.
1883. §§Walker, Mrs. Emma. 13 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. ‡Walker, Frederick W. Hunslet, Leeds.
1897. §Walker, George Blake. Tankersley Grange, near Barnsley.
1894. *WALKER, G. T., M.A. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. §§Walker, Horace. Belvidere-road, Prince's Park, Liverpool.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
1855. ‡WALKER, J. J., M.A., F.R.S. 12 Denning-road, Hampstead, N.W.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, S.E.
1888. ‡Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1895. §WALKER, William G., A.M.Inst.C.E. 47 Victoria-street, S.W.
1896. §Walker, Colonel William Hall. Gateacre, Liverpool.
1896. §§Walker, W. J. D. Lawrencetown, Co. Down, Ireland.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1897. §Wallace, Chancellor. Victoria University, Toronto, Canada.
1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. Weston Lodge, 16 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1895. ‡WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Chevening, Montague-road, Edgbaston, Birmingham.
1883. ‡*Walmesley, Oswald. Shevington Hall, near Wigan.*
1894. *Walmisley, A. T., M.Inst.C.E. 9 Victoria-street, S.W.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1895. §§WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡Ward, A. W., M.A., Litt.D., late Principal of Owens College, Manchester.
1874. ‡Ward, F. D., J.P., M.R.I.A. Wyncroft, Adelaide Park, Belfast.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, D.Sc., F.R.S., F.L.S., Professor of Botany, University of Cambridge. New Museums, Cambridge.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, J.P., F.S.A. Lenoxvale, Belfast.
1887. ‡WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.

Year of Election.

1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.
1884. *Ward, John William. Newstead, Halifax.
1883. ‡Ward, Thomas. Arnold House, Blackpool.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.
1878. §WARINGTON, ROBERT, F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. High Bank, Harpenden, St. Albans, Herts.
1882. ‡Warner, F. I., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. §§Warr, A. F. 4 Livingstone-drive North, Liverpool.
1896. §§Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1875. ‡Warren, Algernon. 6 Windsor-terrace, Clifton, Bristol.
1887. ‡WARREN, Major-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, S.W.
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Lieut.-Colonel J. Oak Lodge, Court-road, Eltham, Kent.
1870. ‡Waters, A. T. H., M.D. 60 Bedford-street, Liverpool.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, W.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. 34 Smallbrook-street, Birmingham.
1883. ‡Watson, C. Knight, M.A. 49 Bedford-square, W.C.
1892. §Watson, G., Assoc. M.Inst.C.E. Athenæum-buildings, Park-lane, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. 5 Loraine-terrace, Low Fell, Gateshead.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 16 St. Mary's-road, Bayswater, W.
1894. *WATSON, W., B.Sc. 7 Upper Cheyne-row, S.W.
1892. §Watson, William, M.D. Slateford, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones, Cumberland.
1882. ‡Watt, Alexander. 19 Brompton-avenue, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. 10 Rivers-street, Bath.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Little Don Waterworks, Langsett, near Penistone.
1896. §§Watts, W. H. Elm Hall, Wavertree, Liverpool.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.

Year of Election.

1883. *WATTS, W. W., M.A., F.G.S., Assistant Professor of Geology in the Mason Science College, Birmingham.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. ‡Webb, Sidney. 4 Park-village East, N.W.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886. §WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, E.C.
1882. *Webster, Sir Richard Everard, LL.D., Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, S.W.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. 48 Westendstrasse, Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. *Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, S.W.
1894. §Weld, Miss. Conal More, Norham Gardens, Oxford.
1876. *WELDON, W. F. R., M.A., F.R.S., F.L.S., Professor of Comparative Anatomy and Zoology in University College, London. 30A Wimpole-street, W.
1880. *Weldon, Mrs. 30A Wimpole-street, W.
1897. §Welford, A. B., M.B. Woodstock, Ontario, Canada.
1881. §Wellcome, Henry S. Snow Hill Buildings, E.C.
1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1894.§§Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1887. **Welton, T. A.* *38 St. John's-road, Brixton, S.W.*
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1897. §Western, Alfred E. 36 Lancaster Gate, W.
1882. *Westlake, Ernest, F.G.S. Vale of Health, Hampstead, N.W.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡WETHERED, EDWARD B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1885. *WHARTON, Admiral Sir W. J. L., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. Florys, Prince's-road, Wimbledon Park, Surrey.
1888. ‡Wheatcroft, William G. 6 Widcombe-terrace, Bath.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.

Year of Election.

1866. ‡*Wheatstone, Charles C.* 19 *Park-crescent, Regent's-park, N.W.*
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. Bank House, 16 Old Broad-street, E.C.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1893. *WHETHAM, W. C. D., M.A. Trinity College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. St. George's Vicarage, Battersea Park-road, S.W.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Freda, Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. §Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. 5 King-street, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 311 Union-street, Aberdeen.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. 6 Southwell-gardens, S.W.
1883. *White, Mrs. 66 Cambridge-gardens, Notting Hill, W.
1895. ‡White, Philip J., M.B., Professor of Zoology in University College Bangor, North Wales.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 66 Cambridge-gardens, Notting Hill, W
1886. *White, William. The Ruskin Museum, Sheffield.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. The Admiralty, Whitehall, S.W.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 20 Beeches-road, West Bromwich.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡Whitla, Valentine. Beneden, Belfast.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Headingley, Leeds.
1897. §Whittaker, E. T. Trinity College, Cambridge.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. Highlands, Ellington-road, Ramsgate.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Linthorpe, Tyndall's Park, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1897. §Wickett, M., Ph.D. 339 Berkeley-street, Toronto, Canada.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.

Year of
Election.

1865. ‡Wiggin, Sir H., Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1896.§§Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1883. ‡Wigglesworth, Mrs. Ingleside, West-street, Scarborough.
1881. *Wigglesworth, Robert. Beckwith Knowle, near Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *Wilde, Henry, F.R.S. The Hurst, Alderley Edge, Manchester.
1896. §Wildermann, Meyer. 22 Park-crescent, Oxford.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1892. ‡Wilkinson, Rev. J. Frome., M.A. Barley Rectory, Royston, Herts.
1886. *Wilkinson, J. H. Hamstead Hill, Handsworth, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. Vale Bank, Knutsford, Cheshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1872. ‡Willett, Henry. Arnold House, Brighton.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.
1887. ‡Williams, Sir E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1857. ‡Williams, Rev. James. Llanfairynghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entryhill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Midwood, Christchurch-road, Bournemouth.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katherine. Llandaff House, Pembroke Vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡Williams, Matthew W. 26 Elizabeth-street, Liverpool.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. 28 Compayne-gardens, West Hampstead, London, N.W.
1883. ‡Williams, T. H. 21 Strand-street, Liverpool.
1888. ‡*Williams, W. Cloud House, Stapleford, Nottinghamshire.*
1877. *Williams, W. Carleton, F.C.S. Firth College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *Williamson, Alexander William, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. High Pitfold, Haslemere.
1857. ‡Williamson, Benjamin, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1895.§§Willink, W. 14 Castle-street, Liverpool.
1895. ‡Willis, John C., M.A., Senior Assistant in Botany in Glasgow University. 8*i* Lawrence-place, Dowanhill, Glasgow.
1896. §Willison, J. S. Toronto.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.

Year of Election.

1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 19 Little Queen-street, Westminster, S.W.
1874. ‡WILSON, Major-General Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. The Athenæum Club, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, N.W.
1875. ‡WILSON, GEORGE FERGUSSON, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1895. ‡Wilson, Gregg. The University, Edinburgh.
1883. *Wilson, Henry, M.A. Farnborough Lodge, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1896. §§Wilson, John H., D.Sc., F.R.S.E., Professor of Botany, Yorkshire College, Leeds.
1865. ‡WILSON, Ven. JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.
1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., F.R.S. Daramona House, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., Professor of Anatomy in Mason College, Birmingham.
1887. ‡Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1893. *Winter, G. K., M.Inst.C.E., F.R.A.S. C/o The Union Bank of London, 3 Princes-street, E.C.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1894. ‡Witley, Arthur. 17 Acton-lane, Harlesden, N.W.
1888. ‡WODEHOUSE, E. R., M.P. 56 Chester-square, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1884. ‡Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. Bedford College, Baker-street, W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §§Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.

Year of Election.

1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡Wood, Sir H. Trueman, M.A. Society of Arts, John-street, Adelphi, W.C.
1883. *Wood, James, LL.D. Grove House, Scarisbrick-street, Southport.
1881. ‡Wood, John, B.A. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Hazelwood, 14 Lethbridge-road, Southport.
1893. ‡Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq., Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1890. *Wood, Robert H., M.Inst.C.E. 15 Bainbrigge-road, Headingley, Leeds.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
1845. *Wood, Rev. William Spicer, M.A., D.D. Higham Vicarage, Rochester.
1863. *Woodall, John Woodall, M.A., F.G.S.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, N.W.
1896. §Woodhead, G. Sims, M.D. 1 Nightingale-lane, Balham, S.W.
1888. *Woodiwiss, Mrs. Alfred. Weston Manor, Birkdale, Lancashire.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*Woods, Edward, M.Inst.C.E. 8 Victoria-street, Westminster, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. 16 Adelaide-street, Leamington.
Woods, Samuel. 1 Drapers'-gardens, Throgmorton-street, E.C.
1888. ‡Woodthorpe, Colonel. Messrs. King & Co., 45 Pall Mall, S.W.
1887. *Woodward, Arthur Smith, F.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *Woodward, C. J., B.Sc., F.G.S. 97 Harborne-road, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1870. ‡Woodward, Horace B., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1894. *Woodward, John Harold. 6 Brighton-terrace, Merridale-road, Wolverhampton.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. §Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. The Hill, Stourbridge.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, N.W.

Year of Election.

1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1896. §§Wrench, Edward M., F.R.C.S. Park Lodge, Bastow.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1857. ‡Wright, E. Perceval, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. §Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
1831. Wright, T. G., M.D. 91 Northgate, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Thomas, M.P., M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1897. §Wyld, Frederick. 127 St. George-street, Toronto, Canada.
1883. §Wyllie, Andrew. Sandown, Southport.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡Wynne, Arthur Beevor, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1883. §Yates, James. Public Library, Leeds.
1896. §§Yates, Rev. S. A. Thompson. 43 Phillimore-gardens, S.W.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, S.E.
1886. *Young, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, S.W.
1894. *Young, George, Ph.D. Firth College, Sheffield.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡Young, John, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1896. §§Young, J. Denholm. 88 Canning-street, Liverpool.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1883. *Young, Sydney, D.Sc., F.R.S., Professor of Chemistry in University College, Bristol. 10 Windsor-terrace, Clifton, Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, United States.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States. (3909, Locust-street).
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor F. Beilstein. 8th Line, No. 17, St. Petersburg.
1894. Professor E. van Beneden. The University, Liége, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1894. Deputy Surgeon-General J. S. Billings. Washington, United States.
1893. Professor Christian Bohr. 62 Bredgade, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. Fürkenstrasse 3, Vienna, IX.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Harvard Medical School, Boston, Massachusetts, United States.
1890. Professor Brentano. 1 Maximilian-platz, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale College, New Haven, Conn., United States.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, United States.
1897. M. C. de Candolle. Geneva, Switzeriand.
1887. Professor G. Capellini. Royal University of Bologna. (65 Via Zamboni).
1887. Professor J. B. Carnoy. Rue du Canal 22, Louvain.
1887. Hofrath Dr. H. Caro. Mannheim.
1894. Emile Cartailhac. Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1894. Dr. A. Chauveau. The Sorbonne, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1855. Professor Dr. Ferdinand Cohn. The University, Breslau, Prussia.
1873. Professor Guido Cora. 74 Corso Vittorio Emanuele, Turin.
1880. Professor Cornu. Rue de Grenelle 9, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome. (5 Piazza S. Pietro in Vincoli).

Year of Election.

1889. W. H. Dall. United States Geological Survey, Washington, D.C., United States.
1872. Professor G. Dewalque. Liége, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. Liége, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Holland.
1892. Professor F. Elfving. Helsingfors, Finland.
1894. Professor T. W. W. Engelmann. Berlin.
1892. Professor Léo Errera. 1 Place Stéphanie, Brussels.
1874. Dr. W. Feddersen. 9 Carolinenstrasse, Leipzig.
1886. Dr. Otto Finsch. Bremen.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1894. Professor Léon Fredericq. Rue de Pitteurs 18, Liége, Belgium.
1894. Professor C. Friedel. 9 Rue Michelet, Paris.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague.
1892. Professor Dr. Gustav Fritsch. Roon Strasse 10, Berlin.
1881. Professor C. M. Gariel. 6 Rue Edouard Detaille, Paris.
1866. Dr. Gaudry. 7 bis Rue des Saints Pères, Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor J. Willard Gibbs. Yale University, New Haven, Conn., United States.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, D.C., United States.
1892. Daniel C. Gilman. President of the Johns Hopkins University, Baltimore, United States.
1870. William Gilpin. Denver, Colorado, United States.
1889. Professor Gustave Gilson. Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, D.C., U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass., U.S.A.
1872. Professor James Hall. Albany, State of New York.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1887. Fr. von Hefner-Alteneck. Berlin.
1893. Professor Paul Heger. Rue de Drapiers 35, Brussels.
1894. Professor Ludimar Hermann. The University, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoolog. Museum, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, N.Y., U.S.A.
1887. Professor W. His. Königstrasse 22, Leipzig.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Holland.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, Rhode Island, United States.
1884. Professor C. Loring Jackson. 12 Wave-street, Cambridge, Massachusetts, United States.
1867. Dr. J. Janssen, LL.D. L'Observatoire, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.

Year of Election.

1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. 32 East Preston-street, Baltimore, U.S.A.
1887. Professor C. Julin. Liége.
1876. Dr. Giuseppe Jung. 7 Via Principe Umberto, Milan.
1887. *M. Akin Károly. 92 Rue Richelieu, Paris.*
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tōkyō, Japan.
1873. Professor Dr. Felix Klein. Wilhelm Weber Strasse 3, Göttingen.
1894. Professor L. Kny. Kaiser-Allee 92, Wilmersdorf, bei Berlin.
1896. Dr. Kohlrausch. Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. Basle, Switzerland.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin, N.W.
1894. Maxime Kovalevsky. Beaulieu-sur-Mer, Alpes-Maritimes.
1887. Professor Krause. 31 Brueckenallee, Berlin, N.W.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. *Lieutenant R. Kund. German African Society, Berlin.*
1887. Professor A. Ladenburg. Kaiser Wilhelm Str. 108, Breslau.
1887. Professor J. W. Langley. 847½ Fairmount-street, Cleveland, Ohio, United States.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution. Washington, United States.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, United States.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1887. Professor A. Lieben. Wasågasse 9, Vienna, IX.
1883. Dr. F. Lindemann. Georgenstrasse 42, Munich.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society. Bremen.
1887. Professor Dr. Georg Lunge. The University, Zurich.
1871. Professor Jacob Lüroth. The University, Freiburg-in-Breisgau, Germany.
1871. Professor Dr. Lütken. Nörregade 10, Copenhagen, Denmark.
1894. Dr. Otto Maas. Wurzerstrasse 16, Munich.
1887. Dr. Henry C. McCook. 3,700 Chestnut-street, Philadelphia, United States.
1867. Professor Mannheim. Rue de la Pompe 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, New Haven, Conn., United States.
1887. Dr. O. A. Martius. Voss Strasse 8, Berlin, W.
1890. Professor E. Mascart, Membre de l'Institut. 176 Rue de l'Université, Paris.
1887. Professor D. I. Mendeléeff, D.C.L. St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1848. Professor J. Milne-Edwards. 57 Rue Cuvier, Paris.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, United States.
1894. Professor G. Mittag-Leffler. Djuvsholm, Stockholm.
1893. Professor H. Moissan. The Sorbonne, Paris (7 Rue Vauquelin).
1877. Professor V. L. Moissenet. 4 Boulevard Gambetta, Chaumont, Hte. Marne, France.
1894. Dr. Edmund von Mojsisovics. Strohgasse 26, Vienna, III3.
1897. Professor Oskar Montelius. Stockholm, Sweden.
1897. Professor E. W. Morley. Cleveland, Ohio, U.S.A.

Year of Election.

1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1889. Dr. F. Nansen. Christiania.
1894. Professor R. Nasini. Istituto Chimico dell' Università, Padua, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. 1620 P.-street, Washington, D.C., United States.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1894. Baron Osten-Sacken. Heidelberg.
1890. Professor W. Ostwald. Brüderstrasse 34, Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, United States.
1890. Maffeo Pantaleoni, Director of the Royal Superior School of Commerce. Bari, Italy.
1895. Professor F. Paschen. Nelkenstrasse 14, Hannover.
1887. Dr. Pauli. Feldbergenstrasse 49, Frankfurt a. M., Germany.
1890. Professor Otto Pettersson. Hogskolas Laboratorium, Stockholm.
1894. Professor W. Pfeffer, D.C.L. The University, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, D.C., United States.
1886. Professor Putnam, Secretary of the American Association for the Advancement of Science. Harvard University, Cambridge, Massachusetts, United States.
1887. Professor Georg Quincke. Friederich bau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich (Sonnen-Strasse 7).
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1886. Rev. A. Renard. Rue du Roger, Gand, Belgium.
1897. Professor Dr. C. Richet. Faculté de Médecine, Paris, France.
1873. Professor Baron von Richthofen. Kurfürstenstrasse 117, Berlin.
1896. Dr. van Rijckevorsel. Parklaan 7, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massachusetts, United States.
1881. Professor Henry A. Rowland. Baltimore, United States.
1895. Professsr Karl Runge. Körnerstrasse 19A, Hannover.
1894. Professor P. H. Schoute. The University, Groningen, Holland.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1883. Dr. Ernst Schröder. Gottesanerstrasse 9, Karlsruhe in Baden.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1873. Dr. A. Shafarik. Weinberge, Kopernicus Gasse 422, Prague.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands. Utrecht.
1887. Professor Count Solms. Bot. Garten, Strassburg.
1887. Ernest Solvay. 25 Rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. Box 621, Cincinnati, Ohio, United States.
1889. Professor G. Stefanescu. Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. The University, Breslau.
1884. Professor Robert H. Thurston. Sibley College, Cornell University, Ithaca, New York, United States.
1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.

Year of Election.

1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, United States.
Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor J. H. van't Hoff. Uhlansstrasse 2, Charlottenburg, Berlin.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.
1886. Professor Jules Vuylsteke. 80 Rue de Lille, Menin, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor Dr. Leonhard Weber. Kiel.
1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.
1887. Dr. H. C. White. Athens, Georgia, United States.
1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.
1887. Professor E. Wiedemann. Erlangen. [C/o T. A. Barth, Johannisgasse, Leipzig.]
1874. Professor G. Wiedemann. Thalstrasse 35, Leipzig.
1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Professor Dr. J. Wislicenus. Liebigstrasse 18, Leipzig.
1887. Dr. Otto N. Witt. 21 Siegmundhot, Berlin, N.W.
1876. Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.
1887. Professor C. A. Young. Princeton College, New Jersey, U.S.A.
1896. Professor E. Zacharias. Botanischer Garten, Hamburg.
1887. Professor F. Zirkel. Lalstrasse 33, Leipzig.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Belfast, Queen's College.
Birmingham, Midland Institute.
Brighton Public Library.
Bristol Naturalists' Society.
Cambridge Philosophical Society.
Cardiff, University College of South Wales.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Albert Memorial Museum.
Glasgow Philosophical Society.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Mechanics' Institute
——, Philosophical and Literary Society of.
Liverpool, Free Public Library and Museum.
——, Royal Institution.
London, Admiralty, Library of the.
——, Anthropological Institute.
——, Arts, Society of.
——, Chemical Society.
——, Civil Engineers, Institution of.
——, East India Library.
——, Geological Society.
——, Geology, Museum of Practical, 28 Jermyn Street.
——, Greenwich, Royal Observatory.
——, Kew Observatory.
London, Linnean Society.
——, London Institution.
——, Mechanical Engineers, Institution of.
——, Meteorological Office.
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Engineers' Institute, Chatham.
——, Royal Geographical Society.
——, Royal Institution.
——, Royal Meteorological Society.
——, Royal Society.
——, Royal Statistical Society.
——, Sanitary Institute.
——, United Service Institution.
——, University College.
——, War Office, Library of the.
——, Zoological Society.
Manchester Literary and Philosophical Society.
——, Mechanics' Institute.
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
Salford, Royal Museum and Library.
Sheffield, Firth College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Swansea, Royal Institution of South Wales
Yorkshire Philosophical Society.
The Corresponding Societies (see list in Report).

EUROPE.

Berlin ....Die Kaiserliche Akademie der Wissenschaften.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra ....Meteorological Observatory.
Copenhagen ...Royal Society of Sciences.
Dorpat, Russia...University Library.
Dresden ....Royal Museum.
Frankfort ......Natural History Society.
Geneva............Natural History Society.
Göttingen ......University Library.
Grätz ....Naturwissenschaftlicher Verein.
Halle ....Leopoldinisch-Carolinische Akademie.
Harlem ....Société Hollandaise des Sciences.
Heidelberg ......University Library.
Helsingfors ......University Library.
Kazan, Russia ...University Library.
Kiel ....Royal Observatory.
Kiev...............University Library.
Lausanne.........The University.
Leyden ....University Library.
Liège ....University Library.
Lisbon ....Academia Real des Sciences.
Milan ....The Institute.
Modena ....Royal Academy.
Moscow ....Society of Naturalists.
—— ....University Library.
Munich ....University Library.
Naples ....Royal Academy of Sciences.
Nicolaieff.........University Library.
Paris ....Association Française pour l'Avancement des Sciences.
—— ....Geographical Society.
—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ....Imperial Observatory.
Rome ....Accademia dei Lincei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
St. Petersburg . University Library.
—— ...Imperial Observatory.
Stockholm ......Royal Academy.
Turin ....Royal Academy of Sciences.
Utrecht ....University Library.
Vienna............The Imperial Library.
—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich............General Swiss Society.

ASIA.

Agra ....The College.
Bombay ....Elphinstone Institution.
—— ....Grant Medical College.
Calcutta ....Asiatic Society.
Calcutta ....Hooghly College.
—— ....Medical College.
—— ....Presidency College.
Ceylon............The Museum, Colombo.
Madras............The Observatory.
—— ....University Library.

AFRICA.

Cape of Good Hope . . . The Royal Observatory.

AMERICA.

Albany	The Institute.
Boston	American Academy of Arts and Sciences.
California	The University.
——	Lick Observatory.
Cambridge	Harvard University Library. American Medical Association.
Chicago	Field Columbian Museum.
Kingston	Queen's University.
Manitoba	Historical and Scientific Society.
Mexico	Sociedad Cientifica 'Antonio Alzate.'
Montreal	Council of Arts and Manufactures.
——	McGill University.
New York	American Society of Civil Engineers.
——	Lyceum of Natural History.
Ottawa	Geological Survey of Canada.
Philadelphia	American Philosophical Society.
——	Franklin Institute.
Toronto	The Observatory.
——	The University.
Washington	Bureau of Ethnology.
——	Smithsonian Institution.
——	The Naval Observatory.
——	United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide	The Colonial Government.
Brisbane	Queensland Museum.
Sydney	Public Works Department.
Victoria	The Colonial Government.

NEW ZEALAND.

Canterbury Museum.

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